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OF OUTER SPACE

CENTRES FOR SPACE SCIENCE AND TECHNOLOGY EDUCATION - A PROGRESS REPORT

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INTRODUCTION

1. The present report focuses on the steps taken to date, the results thereof and the planned follow-up actions on the United Nations initiative to establish a Centre for Space Science and Technology Education in each of the four regional commissions in the developing countries. While practically every aspect of space science and technology can be grouped under four broad categories - basic space science, satellite communications, satellite meteorology and remote sensing - the initial emphasis of the Centres will be on in-depth education, research and applications programmes in satellite meteorology and remote sensing as these relate directly to environmental monitoring and natural resources management.

I. MANDATE

2. The General Assembly, at its forty-fifth session, in its resolution 45/72 of 11 December 1990, endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space (COPUOS) that:

> "... the United Nations should lead, with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in existing national/regional educational institutions in the developing countries." (A/AC.105/456, annex II, para. 4 (n))

II. RATIONALE AND PROPOSALS FOR THE CENTRES

3. The rationale for the establishment of these Centres as well as the summary of the project proposals, contained in documents SAP/90/001-004, entitled "Centres for Space Science and Technology Education",* are presented in the annex to the present report. The summary includes the objectives, output, input, programme, curriculum (annex, table I), equipment (annex, table II), and functioning of the Centres (annex figure 1).

III. STEPS TAKEN TO DATE

4. Following the approval by COPUOS, at its 1990 session, of the recommendation of its Scientific and Technical Subcommittee on the establishment of the Centres for Space Science and Technology Education, the Outer Space Affairs Division developed and published a set of project

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* Documents SAP/90/001-004 are available in the Outer Space Affairs Division, United Nations Headquarters, New York.

documents (SAP/90/001-004, see para. 3 above) which are to serve as the guide for the establishment of the aforementioned Centres in developing countries. The documents were made available to all Member States, the regional commissions concerned (Economic Commission for Africa (ECA), Economic Commission for Latin America and the Caribbean (ECLAC), Economic and Social Commission for Asia and the Pacific (ESCAP) and Economic and Social Commission for Western Asia (ESCWA)) as well as governmental and non-governmental institutions.

Communications and consultations

5. The United Nations Secretariat has also initiated the following communications and consultations in respect of the Centres.

6. On 14 September 1990, the recommendation of COPUOS to the General Assembly on the Centres was communicated to the four regional commissions in the developing countries. Their assistance was sought in identifying potential host countries for the Centre in their respective jurisdiction. They were also requested to collaborate with the Outer Space Affairs Division in organizing the evaluation missions to potential host countries and their institutions. All four regional commissions in the developing countries have declared their interest in participating in the evaluation missions; one of them will do so if United Nations Headquarters or any other source can provide the funding for its representative.

7. On 8 February 1991, the following were sent:

(a) Notes verbales Nos. SAP/91/L.20/ECA, ECLAC, ESCAP and ESCWA (see annex I to the present report) were sent to all Member States in the developing countries requesting them (1) to support both financially and materially the establishment and operation of the Centre in their region, and (2) to indicate their interest in hosting the Centres;

(b) In response to these notes verbales, the following countries have offered to host the Centre in their respective region:

(i) ECA: Kenya, Nigeria and Zimbabwe;

(ii) ECLAC: Argentina, Brazil, Chile and Mexico;

(iii) ESCAP: Bangladesh, China, India, Indonesia, Iran (Islamic Republic of), Malaysia, Pakistan, Sri Lanka and Thailand;

(iv) ESCWA: Iraq, Jordan, Oman, Syrian Arab Republic and United Arab Emirates;

(c) Note verbale No. SAP/91/L.21/Centre (see annex II to the present report) was sent to 37 developed countries of Asia, Australasia, Europe and North America requesting them (1) to participate in the evaluation missions to potential host countries/institutions and (2) to support financially, materially and through institutional linkages the establishment and operation of these Centres.

8. On 1 April 1991, a letter (Ref. No. SAP/91/L.40) was addressed to the Administrator of the United Nations Development Programme (UNDP), requesting the participation and support (financially and material) of UNDP in (a) the evaluation mission and (b) in the establishment and subsequent operation of the Centres, particularly through funding allocations in the 5th UNDP cycle programmes and the UNDP/United Nations Environment Programme (UNEP)/World Bank Global Environment Facility (GEF) Programme.

9. In May/June and September/October 1991, consultation missions were undertaken with the representatives of the Governments of the following nine countries in their respective capitals: Australia, Canada, Finland, Germany, the Netherlands, Norway, Spain, Sweden and the United States of America. These consultation sessions, which took place in the capital of each of these countries, addressed the background and justifications for the Centres, including their programmes, funding arrangements, support from potential host countries, institutional linkages and management structure. The United Nations also used the consultation sessions to appeal to these countries for their financial, material and institutional support for the Centres as described under "Contributions of and responsibilities by the parties to the project" in part II, G of the project documents (SAP/90/001-004). The United Nations has addressed a follow-up letter of appeal to each of these countries. At the present moment, the United Nations is awaiting the response of each of these countries. Additional consultation missions are planned to other countries in 1992.

10. From 4 to 11 November 1991, consultations were held with the Assistant Administrator of the UNDP Regional Bureau for Latin America and the Caribbean and with the representatives of the Assistant Administrators of the UNDP regional bureaux for Africa, Asia and the Pacific and Western Asia. These consultations were follow-up actions to the letter of 1 April 1991 addressed to the UNDP Administrator. At present, each of these bureaux is evaluating the requested support for the Centre in its region of operation, taking into consideration the financial resources that are available for the UNDP fifth cycle regional programmes and the interests of Member States.

11. On 11 and 27 November 1991, the Secretariat requested the 19 countries that have offered to host the four planned Centres to complete a two-page questionnaire titled "Centre for Space Science and Technology Education: host country commitment questionnaire" in order to ascertain the level of commitment of each Government to the Centre it has offered to host. The questionnaire addressed, in part, the "Contributions of, and Responsibilities by the Parties to the (Centre) Project" (part II, G of project documents SAP/90/001-004). The questionnaire focused on four main areas of contribution: (i) personnel, (ii) space requirements (for classrooms, computer room, conference hall, work room, office space for professional and administrative personnel and consultants, library, storage space and living accommodations), (iii) equipment (photographic laboratory, access to international and national communication network, meteorological data receiving and processing facilities, and additional relevant equipment), and (iv) financial resources to support the Centre's actual budget (see annex IV of documents SAP/90/001-004 for budgets estimated in 1990).

IV. CONTRIBUTIONS IN SUPPORT OF THE CENTRES

A. Potential host countries

12. A number of Member States have responded positively to the questionnaire referred to in paragraph 11 above. These include:

(i) Africa

(a) Nigeria. On 7 February 1992, the United Nations received from the Government of the Federal Republic of Nigeria an official confirmation of its decision to offer contributions in the four requested categories - personnel, space, equipment and finance. The Government also offered Obafemi Awolowo University, Ile-Ife, and the University of Nigeria, Nsukka, as host institutions.

(ii) Asia and the Pacific

(a) Islamic Republic of Iran. On 3 December 1991, the United Nations received from the Government of the Islamic Republic of Iran an official confirmation of its decision to offer contributions in the four requested categories - personnel, space, equipment and finance. The Government also offered its Telecommunication University within its Ministry of Posts, Telegraph and Telephone as the host institution;

(b) Indonesia. On 4 December 1991 and on 16 January 1992, the United Nations received from the Government of Indonesia official confirmations of its decision to offer contributions in the four requested categories - personnel, space, equipment and finance. The Government also offered its Institut Teknologi Bandung (ITB) as the host institution;

(c) Sri Lanka. On 9 December 1991, the United Nations received from the Government of Sri Lanka an official confirmation of its decision to offer contributions in two of the four requested categories - personnel and space. The Government also informed the United Nations that the host institution would be the University of Moratuwa, Moratuwa, in collaboration with the Arthur Clarke Centre;

(d) Thailand. On 26 December 1991, the United Nations received from the Government of Thailand an official confirmation of its decision to offer contributions in the four requested categories - personnel, space, equipment and finance. The Government also offered the King Mongkut Institute of Technology Ladkrabang as the host institution;

(e) China. On 30 December 1991, the United Nations received from the Government of China an official confirmation of its decision to offer contributions in the four requested categories - personnel, space, equipment and finance;

(f) India. On 22 January 1992, the United Nations received from the Government of India an official confirmation of its decision to offer contributions in three of the four requested categories - personnel, space and equipment. The Government informed the United Nations that its offer of financial contributions would be made shortly. The Government also offered the Indian Institute of Remote Sensing (IIRS), Dehra Dun, as the host institution.

(g) Malaysia. On 3 February 1992, the United Nations received from the Government of Malaysia an official confirmation of its decision to offer contributions in two of the four requested categories - space and equipment. The Government also informed the United Nations that its proposed host institution will be the University of Malaya.

(iii) Latin America and the Caribbean

(a) Chile. On 27 November 1991, the United Nations received from the Government of Chile an official confirmation of its decision to offer contributions in the four requested categories - personnel, space, equipment and finance. The Government also offered the University of Chile and the Catholic University as host institutions;

(b) Mexico. On 23 January 1992, the United Nations received from the Government of Mexico an official confirmation of its decision to offer contributions in the four requested categories - personnel, space, equipment and finance. The Government also offered to host the Centre through the National Autonomous University of Mexico, the Mexican Institute for Communications and the National Institute for Geography, Statistics and Informatics.

(iv) Western Asia

(a) United Arab Emirates. On 22 January 1992, the United Nations received from the Government of the United Arab Emirates an official confirmation of its decision to offer contributions in three of the four requested categories - personnel, space and equipment. The Government also informed the United Nations that its offer of financial contributions would be made shortly. The Government further offered the United Arab Emirates University as the host institution.

B. Donors

13. A number of potential donors have responded positively to the notes verbales referred to in paragraph 7 (c) above and to the consultations and the follow-up correspondence referred to in paragraph 9 above. These include:

Spain. On 11 December 1991, the United Nations received from the Government of Spain an official confirmation of its interest, in principle, (a) to sponsor the Centre for Space Science and Technology Education in Latin

America and the Caribbean, and (b) to participate in the evaluation mission to the potential host countries/institutions of that Centre.

V. NEXT STEPS

A. Evaluation missions and selection of host countries and institutions

14. Prior to the selection of a host country/institution(s) for a Centre in any of the regions, an evaluation mission to the potential host countries/institutions in the region will be undertaken. The organization of such a mission presupposes that there is adequate funding commitment for the said Centre.

15. The purpose of the evaluation mission (one mission to each regional commission) is to provide an accurate and informative report that could assist in the selection of the host country/institution(s) for each regional Centre. The report of the mission should contain sufficient indications of whether the Governments and host institutions visited will provide the support necessary for the Centre's successful establishment and sustained operation.

16. Those participating in the mission in each region would include some or all of the following: (i) a renowned physical science educator from the region, (ii) a distinguished remote sensing/environmental science educator from outside the region, (iii) a representative from each of the following: (a) each of the potential donor countries, (b) the regional commission, (c) the United Nations Outer Space Affairs Division, (d) the specialized agencies of the United Nations and (e) the UNDP in the country being visited.

B. Agreements between the host countries and the United Nations

17. Following the selection of the Centres' host countries and institutions, the necessary legal instruments will be developed and entered into by the host countries and their institutions, on the one hand, and the United Nations (the Outer Space Affairs Division and the concerned regional commissions) on the other. This initial agreement shall relate only to the establishment and the first four years of operation of each Centre. Thereafter, all decisions on the management and functioning of each Centre will be determined by the Governing Council, on the one hand, and the host country/institution(s) on the other. (See para. 30 of the annex to the present report for further details on the Governing Council.)

C. Developmental activities

18. Upon the signature of the aforementioned initial agreements, a group of experts will be appointed and will be charged with the tasks described in paragraph 29 (b) of the annex to the present report.

D. Inauguration of programme

19. A successful completion of the activities enumerated in paragraph 29 (b) of the annex to this report would be followed by the inauguration of each Centre and the admission of the first set of educators and research and application scientists into the programme of each Centre.

VI. A FIELD TEST AND COMMENTS ON THE CENTRE CONCEPT

A. Field test

20. In collaboration with the Government of Sweden and its institutions (the Swedish Agency for International Technical and Economic Cooperation (BITS), the Swedish Space Corporation Satellitbild and the University of Stockholm), the United Nations began a field test of the concept of the Centres in 1990. This experiment began with the organization of a five-week training course on remote sensing education for educators held in Sweden in May/June 1990. The course was organized in order (i) to test the reality of the concept of the Centres for Space Science and Technology Education and (ii) to determine whether, through their academic and professional activities, the participants could indeed serve as the focal point for indigenous capability development in their respective institutions and countries. The course was attended by 26 African educators.

21. The Government of Sweden and its institutions that co-organized and hosted the 1990 course were very satisfied with its outcome and have invited the United Nations to co-sponsor a similar course in 1992 for the benefit of educators from the international community (developing countries). The United Nations has accepted this invitation.

22. The reports from the representatives of the Government of Sweden, the participants and the United Nations representatives at the 1990 course affirmed that much had been accomplished within the five-week period of the course. Certainly, a more in-depth programme through the Centres for Space Science and Technology Education should achieve much more.

B. Comments

23. Comments on the merits of and the need for the Centres for Space Science and Technology Education and their programmes have been received from 32 entities (including Member States, the United Nations system and the international scientific community). On the whole, the views are very supportive of the Centre concept; some also offered constructive suggestions on programme content and duration, curriculum, increase in the equipment for the Centres, admission of research and application scientists to the Centres' programme, policy and management of the Centres, etc. Most of the proposals have been adopted.

24. A complete text of all the comments received on the concept of the Centres, together with the views of the participants in the above-mentioned 1990 United Nations/Sweden course, are available, on request, from the Outer Space Affairs Division of the United Nations, room S-3260A, telephone (212) 963-7255; fax (212) 963-4879 or (212) 963-7998.

VII. EXISTING REGIONAL TRAINING CENTRES AND THE PLANNED CENTRES FOR SPACE SCIENCE AND TECHNOLOGY EDUCATION

A. The existing regional centres

25. The existing regional remote sensing training centres in Africa (Nairobi; Ile-Ife, Nigeria; Ouagadougou) and Asia (Bangkok) were established to provide Member States with the following: (i) services in surveying, mapping and remote sensing, (ii) training for nationals of Member States in surveying, mapping and remote sensing and (iii) data and results of studies, research and tests carried out by the centres. A number of the centres are undertaking application projects for their Member States and providing short-term training for junior-level technicians from user agencies of the countries they serve. Most of them are not equipped, in terms of both manpower and equipment, to conduct any study, research or tests but none of them is providing any long-term education programme. In 1989, the Centre at Ile-Ife began an application-oriented postgraduate diploma programme in remote sensing. In 1988, the Outer Space Affairs Division of the United Nations coordinated the UNDP-sponsored curriculum development exercise for this programme.

B. The planned Centres

26. The United Nations initiative to establish a Centre in each region will focus on education in space science and technology. Because of the prevailing global circumstances, the initial activities of these Centres will address the development of skill and knowledge in, and the use of space science and technology (Earth Observation satellites including satellite meteorology) in the management of global natural resources and in the monitoring of the global environment. Future activities of the Centres are expected to include basic space sciences and satellite communications. The objectives and output of the planned Centres for Space Science and Technology Education are described in paragraphs 25-27 of the annex to the present report. The participants in the Centres' programme will be university educators and research and application scientists.

27. On the completion of their programme at the Centres, these individuals should become multiplying factors in their chosen profession in their own countries. Individually and collectively, they should become major nuclei around which teams with innovative capability could be formed. The Centres and their graduates should be able to strengthen the capabilities of institutions of higher learning and national and regional remote sensing user assistance and training centres and thereby enhance the capabilities of the

countries and regions they serve, in order to contribute effectively to national, regional and international environmental monitoring and natural resources management programmes.

Annex 1

Note verbale to developing countries on the Centres

Reference: SAP/91/L.20/ESCAP[1]

The Secretariat of the United Nations presents its compliments to the Permanent Representative of ... to the United Nations and has the honour to refer to its resolution 45/72, adopted on 11 December 1990, at its forty-fifth session, in which the General Assembly endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space and directed as follows (document A/AC.105/456, Annex II, para. 4 (n)):

> "Taking into account paragraph 9 (c) of General Assembly resolution 44/46, the United Nations should lead, with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in existing national/regional educational institutions in the developing countries."

It should be noted that the United Nations Secretariat has brought the above recommendation of the Committee on the Peaceful Uses of Outer Spaced and the endorsement of the General Assembly on the establishment of the Centre to the attention of the Executive Secretary of the Economic and Social Commission for Asia and the Pacific (ESCAP) and has requested him to ascertain the interest of ESCAP Member States in hosting this Centre. In this connection, a copy of the working project document No. SAP/90/002 titled "Centre for Space Science and Technology Education (Asia and the Pacific)", which has been prepared by the Outer Space Affairs Division of the Department of Political and Security Council Affairs for the establishment of the Centre in Asia and the Pacific, is attached.[2]

In its resolution 37/90 of 10 December 1982, the General Assembly endorsed the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE-82), and mandated the United Nations Space Applications Programme, among other things, to assist Member States in the development of their indigenous capability in space science and technology. As indicated in para. 5 of the note of the Secretary-General of the United Nations, Ref. SAP/90/L.66 of 17 December 1990, the International Space Year also offers the

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[1] The text of the notes verbales SAP/91/L.20/ECA, ECLAC and ESCWA are identical to this one except for regional identification.

[2] Annex enclosed. Documents SAP/90/001-004 are available in the Outer Space Affairs Division, United Nations Headquarters, New York.

UNITED NATIONS NATIONS UNIES

United Nations and the international community a unique opportunity to achieve major progress in the implementation of the recommendations of UNISPACE-82.

Today, the rational exploitation of the Earth's natural resources, the management of its environment and the programmes needed to achieve these goals are receiving global attention. The building of necessary indigenous capability, at the local level, to support the participation of the developing countries in such programmes is a major necessity. The establishment of the Centre for Space Science and Technology in Asia and the Pacific is a culmination of the efforts of the Space Applications Programme in this direction. The objectives of the Centre are contained in paras. 11 and 12 of the document; the justifications for its establishment are contained in paras. 13 through 16. Para. 17 describes a number of steps that led to the evolution of the project document.

The Outer Space Affairs Division, the Economic and Social Commission for Asia and the Pacific, and other entities of the United Nations system, particularly UNDP, FAO, UNESCO and WMO will participate in the establishment of this Centre. At the present time, arrangements are being made to undertake an evaluation mission to potential host countries/institutions for this Centre. The evaluation mission will assess the viability of the potential host institution(s), i.e. infrastructure, institutional/governmental support, existing educational programmes and all other support that would be provided by each potential host country for the Centre.

A number of ESCAP Member States have already indicated their interest to host this Centre; the United Nations is presently awaiting further indications of interest of ESCAP Member States to host this Centre from the Executive Secretary of ESCAP. The evaluation mission to potential host countries in Asia and the Pacific in respect of this Centre is expected to take place early in the second-half of this year.

The support of Member States for the establishment of the Centre in the ESCAP region is not only essential but of paramount importance. The United Nations invites the participation of the Government, both financially and materially, in the establishment of these Centres. In order that the establishment of this Centre could proceed as scheduled in the attached project document, it would be greatly appreciated if the response of the Government to this note could be sent to the Executive Secretary of ESCAP in Bangkok, by 15 May 1991 with a copy of the response forwarded to the Under-Secretary-General, Department of Political and Security Council Affairs, United Nations Headquarters, New York, N.Y. 10017.

8 February 1991 S.B.

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Annex II

Note verbale to industrialized countries on the Centres

Reference: SAP/91/L.21/Centre

The Secretariat of the United Nations presents its compliments to the Permanent Mission of ... to the United Nations and has the honour to refer to its resolution 45/72, adopted on 11 December 1990, at its forty-fifth session, in which the General Assembly endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space and directed as follows (document A/AC.105/456, Annex II, para. 4 (n)):

> "Taking into account paragraph 9 (c) of General Assembly resolution 44/46, the United Nations should lead with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in exising national/regional educational institutions in the developing countries."

It should be noted that the United Nations Secretariat has brought the above recommendation of the Committee on the Peaceful Uses of Outer Space and the endorsement of the General Assembly on the establishment of these Centres to the attention of the Executive Secretaries of the Economic Commissions and has requested them to ascertain the interest of Member States in their respective region, in hosting these Centres. In this connection, a copy each of the working project documents Nos. SAP/90/001 - 004 titled "Centres for Space Science and Technology Education", which have been prepared by the Outer Space Affairs Division of the Department of Political and Security Council Affairs for the establishment of these Centres in the four economic regions, are attached.[1]

In its resolution 37/90 of 10 December 1982, the General Assembly endorsed the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE-82), and mandated the United Nations Space Applications Programme, among other things, to assist Member States in the development of their indigenous capability in space science and technology. As indicated in para. 5 of the note of the Secretary-General of the United Nations, Ref. SAP/90/L.66 of 17 December 1990, the International Space Year also offers the United Nations and the international community a unique opportunity to achieve major progress in the implementation of the recommendations of UNISPACE-82.

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[1] Annexes enclosed. Documents SAP/90/001-004 are available in the Outer Space Affairs Division, United Nations Headquarters, New York.

UNITED NATIONS NATIONS UNIES

Today, the rational exploitation of the Earth's natural resources, the management of its environment and the programmes needed to achieve these goals are receiving global attention. The building of necessary indigenous capability, at the local level, to support the participation of the developing countries in such programmes is a major necessity. The establishment of the regional Centres for Space Science and Technology is a culmination of the efforts of the Space Applications Programme in this direction. Part II of each of the project documents contains each Centre's objectives (Sections A and B) and the justifications for their establishment (Section C). Section D of Part II describes a number of steps that led to the evolution of these project documents.

The Outer Space Affairs Division, the Regional Economic Commissions and other entities of the United Nations system, particularly UNDP, FAO, UNESCO and WMO will participate in the establishment of these Centres. At the present time, arrangements are being made to undertake evaluation missions to potential host countries/institutions for these Centres. The evaluation missions will assess the viability of the potential host institutions, i.e. infrastructure, institutional/governmental support, existing educational programmes and all other support that would be provided by each potential host country for these Centres.

A number of Member States have already indicated their interest to host the Centre in their respective regions. The United Nations is presently awaiting further indications of interest of other Member States to host the Centre in their region from the Executive Secretary of each of the Economic Commissions. The evaluation mission to each of the regions is expected to take place early in the second half of this year.

The support of Member States for the establishment of these Centres is not only essential but of paramount importance. The United Nations invites the participation of the Government, both financially and materially, in the establishment of these Centres. In order that the establishment of these Centres could proceed as scheduled in the attached project documents, it would be greatly appreciated if the response of the Government to this note could be received by the Under-Secretary-General, Department of Political and Security Council Affairs, United Nations Headquarters, New York, N.Y. 10017, by 15 May 1991.

8 February 1991

S.B.

Annex III

RATIONALE FOR THE ESTABLISHMENT OF THE CENTRES AND SUMMARY OF THE PROJECT PROPOSALS

INTRODUCTION

1. The ever changing state of the planet Earth, brought about in part by man-made interventions, is creating global concerns. Today, these concerns include global desertification, deforestation, soil erosion, acid rain, air pollution, as well as others; they are individually and collectively creating a global change whose magnitude and direction are largely unknown.

2. Many countermeasures aimed at correcting these environmental problems have been proposed and in some cases agreed to at intergovernmental levels. For example, the General Assembly, in its resolution 1721 C (XVI) of 20 December 1961, called for a study on "measures to advance the state of atmospheric science and technology so as to provide greater knowledge of basic physical forces affecting climate and the possibility of large-scale weather modification". Similarly, the Montreal Protocol of 1989 called for international efforts and measures for controlling and subsequently eliminating ozone-destroying pollutants. A number of countries and intergovernmental and non-governmental organizations are studying these problems in order to be able to formulate appropriate policies. For example, the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) responded to the aforementioned General Assembly resolution and mounted the Global Atmospheric Research Programme (GARP) to observe the global atmosphere on an intensive scale and to have an unprecedented description of it through one annual cycle. The achievements of GARP are well known, including (i) the development of new and advanced methods of data acquisition and analysis, (ii) marked improvements in weather forecasting and (iii) accelerated progress in climate research by stimulating the development of global models.

3. Today, the maintenance of global forests is an essential part of any climate protection programme. At its first of three meetings in a tropical forest country (Brazil) in June 1988, the International Tropical Timber Organization added its voice to the global demand for tropical rain forest conservation and reforestation. In June 1992, Brazil will also host the United Nations Conference on Environment and Development, with a view to forging the emergence of cooperative, collective and global environmental conservation and management strategies.

I. ENVIRONMENTAL INFORMATION: EXPLORING THE EARTH FROM SPACE

4. In the last two decades, the world has witnessed the evolution of the observation of the Earth from space, a process that has introduced new dimensions into the collection of Earth resources and environmental data. Of

equal importance is the rapid analysis and effective utilization of these data in a coherent manner in order to establish the trend of ongoing global changes.

5. Experiences gained from regional and global research efforts are now being transferred to a number of major global environmental and resource development programmes; Earth observation satellites will serve as significant and essential tools in these endeavours.

6. Specifically, the international community is now embarking on a number of long-term programmes such as the International Geosphere-Biosphere Programme (IGBP) and Mission to Planet Earth (MPE). The objective of IGBP is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, including the changes that are occurring in the system, and the manner in which they are influenced by human activities. In order to facilitate regional collaboration and research efforts on these global change issues, ICSU, the sponsor of IGBP, plans to establish a network of regional research centres around the world. Through MPE, a programme initiated by most of the space-faring nations, internationally coordinated space-based platforms will chart pollution, deforestation, the greenhouse effect, depletion of the ozone layer and other threats to the Earth's environment. The Joint Communiqué of the Economic Summit held in Paris, in July 1989, added its voice to the global concern on the interrelationship between the state of the Earth's atmosphere and the well-being of mankind on Earth by concluding that decisive action was urgently needed to understand and protect the Earth's ecological balance, and urging all countries to give further impetus to scientific research on environmental issues, to develop necessary technologies and to make clear evaluations of the economic costs and benefits of environmental policies.

7. Because of the ever-expanding frontier of knowledge in science and technology, including Earth observation from space, the acquisition, transmission, processing, analysis and subsequent utilization of environmental information in social and economic development programmes will be intensified with the passage of time. The latest effort in this regard is the microwave sensor system which, because of its all-weather capability, can penetrate rain and clouds, thus enhancing the possibilities of obtaining needed information from otherwise cloud-covered uncharted areas such as the tropics.

8. Today many countries, both developed and developing, are applying high-resolution satellite data to upgrade their Earth resources information systems, and in some cases to obtain for the first time information on different aspects of their environment. Such information can serve as a basis for decision-making as well as for monitoring the outcome of past decisions. The availability of such data can assist these countries to better understand and safeguard their immediate environment, as well as provide opportunities for a more efficient management and productive harnessing of their natural resources.

9. Where appropriate and relevant, major international funding agencies and institutions responsible for bilateral aid have requested the use of such

environmental data in the execution of projects they fund. During the past few years, the United Nations and its specialized agencies (such as the United Nations Environment Programme (UNEP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the World Bank) and the Commission of the European Communities (CEC) have employed remote sensing data, especially the data acquired by the Landsat Thematic Mapper (TM), SPOT and MOS satellites for use in programmes and projects in developing countries. In this connection, and through a number of Executing Agencies, UNDP is carrying out more than 200 projects that are related to the applications of remote sensing data. Projects to be executed within the Global Environment Facility, a joint programme of the World Bank, UNEP and UNDP, will also make use of remote sensing data.

II. EXISTING LEVEL OF KNOWLEDGE IN THE DEVELOPING COUNTRIES

10. Although all countries are contributing to global environmental problems, all countries do not have the requisite capability needed for their solution. The contributions of the developing countries to MPE and IGBP will also be limited.

11. Among the many factors that create bottlenecks in project implementation in the developing countries, only those that are related to the development of indigenous capability are addressed in the present report. These factors include: (i) the shortage of qualified human resources at the local level and (ii) the resulting dependence of most ongoing projects, at the local level, on foreign expertise. Once the latter is withdrawn, such projects often falter; one of the major reasons for such failures is that the country counterpart is generally not versed in the fundamentals of the principles/concepts being applied. Furthermore, country-counterparts often acquire their knowledge through short term training courses, which are mostly applications-oriented and are usually conducted abroad. Through short-duration courses or on-the-job training, such individuals are often taught skills that can be used to execute specific tasks. In most instances, it is impossible to adapt such skills to other tasks without a fundamental knowledge and an understanding of the principles and methodology involved. Only in-depth education can provide such knowledge and skills.

III. NEEDED: IN-DEPTH LONG-TERM EDUCATION

12. Most of the activities being executed in the developing countries either through bilateral aid or by international funding agencies are also carried out as part of a "technology transfer" process. However, technology transfer can lead to knowledge development if it is pursued, not only with a preoccupation with what a particular technology can do, but also it provides an environment through which local scientists and technologists can gain a good understanding and knowledge of how and why the technology that is being applied works the way it does.

13. There is an emerging consensus within the international community that if technology transfer is to succeed, efforts must be devoted to knowledge development at the local level. Such an approach should provide the participating individuals with the necessary educational opportunities, taking into full consideration the local economic, cultural and infrastructural conditions.

14. At the professional level, an individual should be exposed to the acquisition, transmission, processing, analysis and applications of environmental and natural resources data through an intensive educational process. This approach provides an appropriate environment for the assimilation of the fundamental principles involved, which is critical to a successful development of knowledge in the discipline.

15. The World Bank has also examined the development of indigenous capability through education and training, particularly in Africa. In its 1989 report titled "Sub-Saharan Africa: from crisis to sustainable growth", the World Bank opined that if Africa is to benefit from advances in environmental information systems and related sciences and technologies, it must improve its science and technology education and training and aim at the highest standards for at least a minimum core of specialists. Foreign aid should go towards building excellence and relevance in African science and technology and helping to link institutions to others outside Africa.

16. At its Third Meeting, held at Heidelberg, Germany, from 10 to 12 April 1991, the Advisory Committee of the World Bank's Programme on Environment Information Systems in Sub-Saharan Africa noted that "indeed, most cooperation programmes are geared to short training sessions to fill short-term objectives ...". On education and training, the Committee also noted that:

"(i) If a country is to have an effective environment information system, it must have policy makers and administrators capable of appreciating the applications and implications of the information, and scientists, engineers, technicians and teachers capable of developing, adapting, applying and teaching the technology. Both education and training are required to build up these skills;

"(ii) Education provides the individual with an understanding of the subject, and training teaches him to carry out specific tasks, when knowledge of the subject as a whole may not be essential. To create the awareness, flexibility and motivation necessary to adjust to rapidly changing conditions, education is likely to be more effective than training for tasks which, because of the nature of new technologies, alter very quickly." a/

17. The Committee concluded its meeting with the following recommendations:

"(i) A professional approach to environment information as the basis for the viable sustainability of environment information systems should be encouraged. Staff capacity must be developed in the short,

medium and long terms. In the short term, needs can be met by training courses and self-training. In the longer term, basic education and university courses must cover environmental concerns and related subjects, including the information aspects, more thoroughly;

"(ii) African university courses relating to environment information should be developed, and they should be tied in with national environment information programmes. Students should have the opportunity to get practical experience in operational systems. The Committee endorses the strengthening of all viable university resources, and university networking is commended;

"(iii) Cooperation based on long-term partnerships should be established between more developed institutions and African ones (both public and private institutions), to ensure the continuity of technology transfer. Such cooperation programmes should include long-term educational and staff-training schemes. The Committee recommends that a review be prepared on who in Africa is offering training, which organizations are twinned, and which universities in Africa and overseas might be interested in twinning arrangements." b/

18. In a recently released report (para. 2.2.2) of Directorate General VIII of the Commission of the European Communities, the latter noted that "conventional approaches to technology transfer, such as training courses and short-term, in-country demonstration projects are useful educational tools, but on their own, they will not result in effective and permanent integration of remotely sensed techniques into operational programmes." c/

19. In identifying the several steps needed to arrive at practical applications of remote sensing for environmental monitoring and natural resources management, the CEC report opined that:

(i) Research and development are needed to integrate remote sensing techniques into resource management systems;

(ii) Research and development of remote sensing data processing, analysis and interpretation provide the scientific basis for application of the techniques. d/

20. The 1987 Brundtland report on the "World Commission on Environment and Development", which was presented to the General Assembly of the United Nations, recommended that "environmental education should be included in and should run throughout the other disciplines of the formal education curriculum at all levels - to foster a sense of responsibility for the state of the environment and to teach students how to monitor, protect and improve it. Global awareness could be fostered by encouraging contacts among teachers from different countries, for instance, in specialized centres set up for this purpose." e/

IV. CENTRES FOR SPACE SCIENCE AND TECHNOLOGY EDUCATION

21. The developing countries would need a highly educated core of (i) specialists who could teach the courses proposed in the World Bank and Brundtland reports and (ii) research and application scientists who could initiate and carry out the research and application programmes enumerated in the CEC report.

22. Between 1983 and 1986, the United Nations Programme on Space Applications (hereafter referred to as "the Programme") also undertook an evaluation of the needs and requests in different aspects of space science and technology which were submitted by Member States. The analyses reveal that there is a major need in the developing countries for intensive indigenous capability development which can only be attained through long-term educational programmes. High on the list of priorities was the need for in-depth education in the fundamentals of the various fields of space science and technology, as well as the need for opportunities to gain experience in a research environment.

23. Beginning in 1985, the United Nations, through the Programme, embarked on a path towards the development of indigenous capability in space science and technology at the local level. The development of the Centres' project documents (SAP/90/001-004) is the culmination of these efforts. The initiative for the establishment of the Centres for Space Science and Technology Education is in agreement with the above proposal of the Brundtland report; it also aims at providing the education programme and research opportunities deemed essential by the World Bank and the CEC reports. The Programme has long concluded that addressing the present imbalance between the human impact on the environment and measures to safeguard it for future generations would require an in-depth and long-term education programme on environmental information systems with emphasis on remote sensing and related technologies through the education of relevant university educators and research and application scientists.

24. In support of the above initiative of the Programme, the General Assembly, at its forty-fifth session, in its resolution 45/72 of 11 December 1990, endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space (COPUOS) that:

> "... the United Nations should lead, with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in existing national/regional educational institutions in the developing countries." (A/AC.105/456, annex II, para. 4 (n))

A. Objectives

25. On the whole, each of the Centres for Space Science and Technology Education will (i) contribute to sustainable development of natural resources (air/water/land) and (ii) provide a crucial supplementary input for biodiversity conservation and other related environmental programmes through the development of in-depth knowledge and skills of educators and research and application scientists in environmental information systems with emphasis on remote sensing, satellite meteorology and relevant technologies at the local level.

26. Specifically, each of the Centres will be established at an existing and viable institution of higher learning or a research centre in each region. The programme of each Centre will:

(a) Develop skills and knowledge of university educators, environmental research scientists and project personnel, initially in remote sensing and related technologies for subsequent application in national development and environmental management programmes;

(b) Assist those educators to develop environmental and atmospheric sciences curricula that they can use to advance the knowledge of their students in their respective institutions/countries;

(c) Develop the skills of the environmental research scientists and project personnel in the design, development and application of remote sensing techniques in natural resources management and biodiversity protection;

(d) Assist the educators and research and application scientists who have completed the programme at the Centres to undertake pilot projects, and to use the knowledge and skills they have acquired at the Centres in their teaching and research activities in their respective countries;

(e) Support those educators, scientists and project personnel who have completed this programme, with expertise from the Centres and other appropriate international institutions, and to invite them regularly to workshops and seminars organized by the Centres so that they can refresh their knowledge;

(f) Enhance regional cooperation in space science and technology programmes related to environmental monitoring and natural resources management, and support and contribute to the work of institutions of higher learning in each region and the activities of national/regional remote sensing user assistance and training centres.

B. Output of the Centres

27. The Centres would achieve the following:

(a) Contribute significantly to indigenous capability development in environmental information systems such as remote sensing, including satellite meteorology and related environmental disciplines in each participating country and region;

(b) Enhance scientific and technical education in each participating country and region;

(c) Enhance the quality and quantity of contributions of graduates towards the overall development of their respective nations and towards the management of the resources and the environment of their countries;

(d) Strengthen the capabilities of institutions of higher learning and national and regional remote sensing user assistance and training centres;

(e) Assist user agencies in Member States to strengthen their capabilities in the use of remote sensing for the management of their natural resources and environment;

(f) Enhance the capabilities of the countries and regions they serve to contribute effectively to national, regional and international environmental monitoring and natural resources management programmes.

C. Curriculum

28. The curriculum of each of the Centres will address in-depth understanding and subsequent integration of space science and technology into environmental monitoring and natural resources management programmes. A survey of the status of education programmes and materials in each region will be used to determine the level and scope of programmes to be included in the curriculum of each Centre. Through this process, participating educators should be part of the solution to the problems that confront their respective societies and should be equipped to provide their students and their own communities with the requisite knowledge in those disciplines. A general outline of a proposed curriculum is shown in table I below; this outline will be modified on the basis of the recommendations of a panel of educators who are being invited to assess the education programmes in each region.

D. Programme of the Centres

29. In order to achieve the objectives outlined above, the establishment of each Centre is designed to be implemented in four phases.

(a) Phase 1 (preparatory activities) includes a number of parallel preparatory activities, such as:

(i) Identification of and negotiation with the host Government/institutions;

(ii) Raising of necessary funds and securing technical support to establish the Centres;

(iii) Evaluation of facilities and resources being provided by host Government/institutions.

(b) Phase 2 (development activities): consists of the hiring of a group of experts whose responsibilities will include the following:

(i) Assessment of the education levels in each region (e.g., existing university courses and research programmes, audiovisual materials, etc.);

(ii) Development of each Centre's curriculum on the basis of the assessment in (i) above;

(iii) Identification and acquisition as well as development of scientific and technical education materials appropriate for each region;

(iv) Identification, acquisition and installation of necessary equipment and laboratory facilities (see table II below) and the hiring and training of support personnel in the use and maintenance of the equipment and facilities;

(v) Identification and recommendation of professional personnel, including visiting scholars within the region and from the international community, to be recruited for the Centres;

(c) Phase 3 (operational phase) will focus on the operational aspect of the Centre and will include the following:

(i) Hiring of each of the Centre's staff;

(ii) Organizing and implementing the education programme for natural, physical and environmental science educators and scientists;

(iii) Organizing workshops for secondary and primary school teachers;

(iv) Providing research, education and application support services for national and regional institutions;

(v) Organizing a "continuing education" programme at each Centre for educators and research and application scientists, including graduates of the Centres;

(vi) Extending invitations to Member States to nominate able candidates from their academic and research institutions to participate in the various programmes of each of the Centres.

(d) Phase 4 (practical realization). Graduates of the Centres will:

(i) Return to their respective countries to implement their own pilot projects;

(ii) With the aid of the materials developed at each Centre, introduce the knowledge acquired into the education curricula and research and application activities in their own and in other institutions in their country;

(iii) Each Centre will organize evaluation workshops that will assess each participant's pilot project and provide feedback on the efficacy of each Centre's education and research programmes.

E. Management

30. Each of the Centres is to be managed by a governing council consisting of the following: (i) a representative of the host country, (ii) two representatives of the participating countries of the region, (iii) a representative of each of the donor countries, (iv) a representative of the Centre and (v) the representative(s) of the executing agency (in each case, this shall include a representative of the Outer Space Affairs Division of the United Nations, of the concerned regional commission and of the appropriate United Nations agencies). Figure I below shows the functioning of each Centre.

Notes

a/ "Present status of the Programme", Environmental Division for Africa, Technical Department, World Bank, August 1991, pp. 7 and 8.

b/ Ibid., pp. 2 and 3.

c/ "Remote Sensing of the Sahelian Environment", Commission of the European Communities, Technical Centre for Agriculture and Rural Cooperation, Lomé Convention, 1990, pp. 12 and 13.

d/ Ibid., pp. 69 and 70.

e/ See A/42/427, annex.

Table I

OUTLINE OF PROPOSED CURRICULUM

(a) Development of analytical skills (physics, mathematics, computer science, photogrammetry and cartography)

(b) Basic radiometry

(c) Fundamentals of meteorology

(d) Physics of imaging, including the principles of data acquisition, transmission and reception

(e) Principles of photo-interpretation (analogue and digital)

(f) Skills and knowledge development in remote sensing technology, including geographical information systems (GIS)

(g) Development of skills in applying remote sensing technology and GIS to specific application projects

(h) Development of research programmes

(i) Development and design of education and demonstration materials

(j) Curriculum development

(k) Development of skills and knowledge in computer-aided education

(l) Establishment and management of information systems

(m) Execution of research and application projects

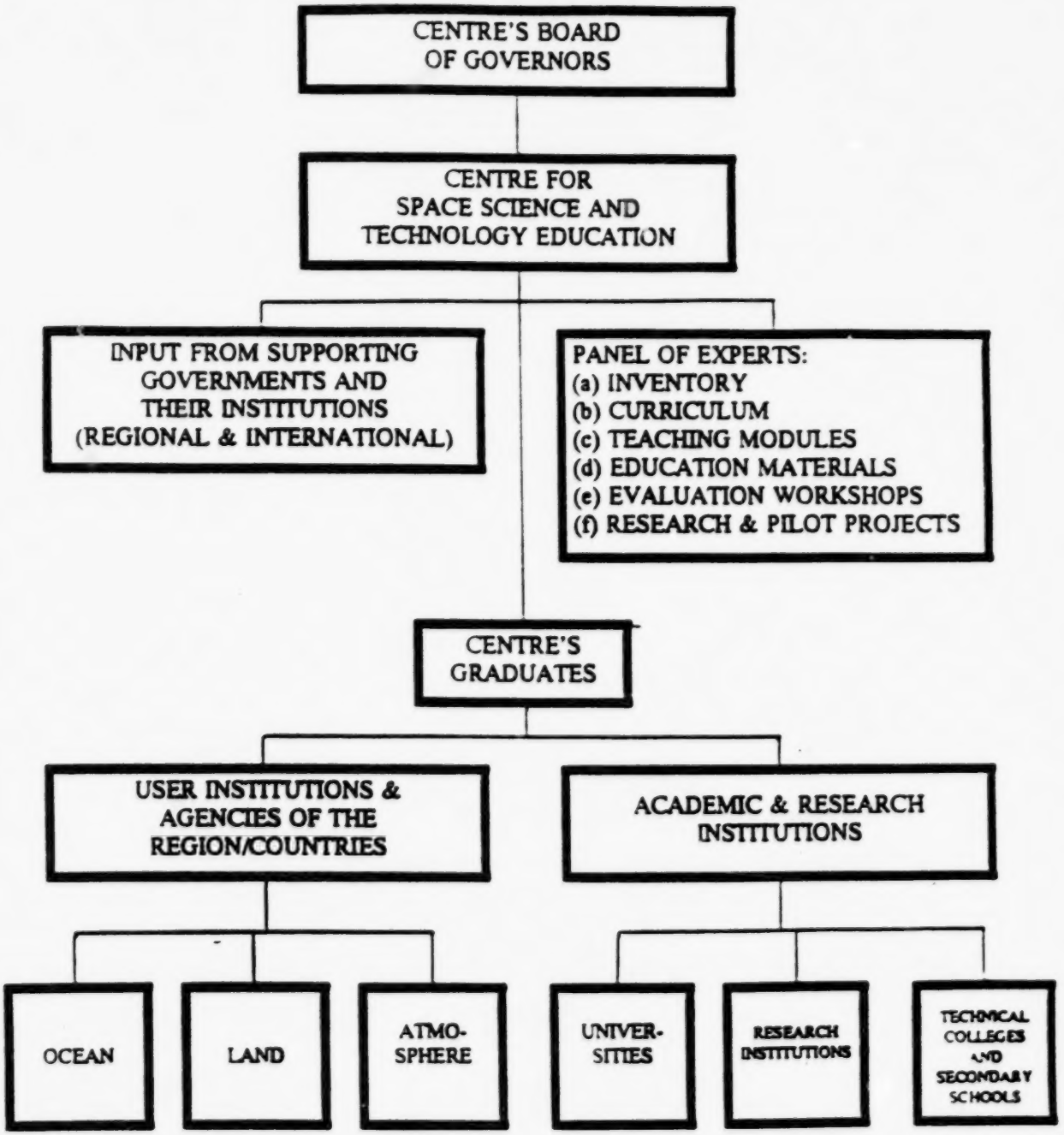
(n) Weekly seminars on special topics on space technology

Table II

LIST OF EQUIPMENT FOR EACH CENTRE

(i)	Twenty microcomputer systems; six of these should have the potential for handling geographic information systems and relevant computer software for image analysis
(ii)	2 multi-channel radiometers for ground truth determination
(iii)	Photographic cameras (2) 35 mm
(iv)	35 mm slide-projectors (3)
(v)	Overhead projectors (3)
(vi)	Video cassette recorders (2); colour T.V. set (2)
(vii)	Office supplies
(viii)	Projection screens (2)
(ix)	Photographic supplies
(x)	Drafting supplies and lettering equipment
(xi)	Voltage regulators
(xii)	Dark room equipment
(xiii)	Audio cassette tape recorders (2)
(xiv)	A photo-copying machine
(xv)	Office furnishings
(xvi)	A small scale meteorological satellite receiving station
(xvii)	Satellite remote sensing images and air photographs
(xviii)	Three vehicles (2 field vehicles (Jeeps) and a car)
(xix)	Laboratory stereoscopes (17)
(xx)	Portable independent communication equipment for voice and data transmission/reception
(xxi)	Replacement parts, and other consumables, for the equipment listed above.

FIGURE 1. THE FUNCTIONING OF THE CENTRE



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COMMITTEE ON THE PEACEFUL USES
OF OUTER SPACE

REPORT ON THE UNITED NATIONS INTERNATIONAL TRAINING COURSE ON REMOTE SENSING APPLICATIONS FOR ENVIRONMENTAL ASSESSMENT AND MONITORING, CO-SPONSORED AND HOSTED BY THE GOVERNMENT OF THE UNITED STATES OF AMERICA

(Sioux Falls, South Dakota, 9 September-4 October 1991)

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INTRODUCTION

A. Background

1. At its thirty-third session, in June 1990, the Committee on the Peaceful Uses of Outer Space endorsed the activities of the United Nations Programme on Space Applications for 1991 as proposed by the Expert on Space Applications and as recommended by its Scientific and Technical Subcommittee at its twenty-seventh session. Subsequently, the General Assembly, at its forty-fifth session, endorsed the activities of the Programme for 1991 (resolution 45/72 of 11 December 1990).

2. In response to resolution 45/72 and in accordance with the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), the United Nations Outer Space Affairs Division organized an international training course on remote sensing applications for environmental assessment and monitoring.

3. The United Nations International Training Course on Remote Sensing Applications for Environmental Assessment and Monitoring, through the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), was organized in cooperation with the Government of the United States of America and hosted by USGS Earth Resource Observation System (EROS) Data Center for the benefit of Member States throughout the world.

4. The present report, which covers the background, objectives and organization of the training course as well as a summary of the lectures, has been prepared by the Outer Space Affairs Division in cooperation with the EROS Data Center for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. Participants in the course will report to the appropriate authorities in their respective countries.

B. Organization of the course

5. Invitations to nominate candidates for the training course were sent by the co-sponsors to developing countries worldwide, and more than 200 applications were received. The co-sponsors jointly selected 23 participants and 2 observers from the following 25 countries: Argentina, Botswana, Bulgaria, Chile, China, Costa Rica, Côte d'Ivoire, Cyprus, Ecuador, Fiji, Gambia, Indonesia, Israel, Kenya, Malawi, Mexico, Mongolia, Nigeria, Peru, Philippines, Spain, Sri Lanka, Tunisia, Uganda and Venezuela.

6. The Government of the United States of America provided the cost of international air travel as well as the daily subsistence allowance for 23 participants.

7. The programme of the course (see the annex to the present report) was designed jointly by the United Nations Outer Space Affairs Division, USGS, NOAA and NASA. The United Nations was responsible for the overall external organization arrangements; the Government of the United States of America, through USGS, coordinated international travel as well as local arrangements and provided technical equipment, materials, course facilities and local transportation. In addition to knowledge gained through classroom and field study, participants were introduced to the life and culture of the United States, including an invitation to dinner by voluntary host families in Sioux Falls.

8. The course was opened by Dr. Donald T. Lauer of the EROS Data Center on behalf of the Government of the United States and Dr. Adigun A. Abiodun, United Nations Expert on Space Applications, on behalf of the United Nations.

I. OVERVIEW OF THE COURSE

A. Scope of the course

9. The course was designed to provide practical training in the processing and applications of satellite and other types of spatial data for environmental assessment and monitoring, with particular emphasis on land processes. The lectures included a review of the fundamentals of remote sensing and Geographic Information Systems (GIS) relating to practical uses of image processing techniques, laying stress on the actual operation of image processing systems as well as on participants' own initiatives for addressing various problems.

10. In order for the participants to undertake hands-on analysis operations using satellite images and GIS, they were provided with PC-compatible computers with CD-ROM readers and the GIS software "IDRISI" developed the Graduate School of Geography, Clark University, Worcester, Massachusetts. NOAA-AVHRR, LANDSAT-MSS/TM, SPOT and various geographic digital data were available for these exercises. A field trip was organized to perform in situ analyses and verify the results of the classroom analysis.

B. Remote sensing fundamentals

11. Remote sensing technology is based on reflection or emission of electromagnetic energy from the surface of materials detected by the sensors. The information gained through this process varies in accordance with the electromagnetic spectrum because each material reflects incoming radiation or emits radiation based on its own spectral properties. Materials reflect or absorb incoming radiation at specific wavelengths; therefore, it is possible to detect materials by sensing such electromagnetic energy with specific sensors. Through this process, a material can be identified through its spectral characteristics. Materials of the Earth's surface differ in their response to energy of various wavelengths according to their chemical and

physical properties, configuration and so on. By analysing the reflections and emissions of these materials one can deduce the identity of a specific Earth surface.

12. Since the launch of Landsat-1 in 1972, space-based remote sensing has served as a very effective tool for land cover classification, ocean observation, geographic analysis and environmental monitoring. Various methods have been developed and tested for the practical uses of remote sensing satellites.

C. Image processing

1. Preprocessing

13. Prior to the practical applications of remote sensing data for various kinds of analysis, one needs to perform data calibrations and corrections and process the acquired digital data into images. Preprocessing is necessary in order to achieve image corrections to compensate for distortion. There are two categories of preprocessing or corrections: radiometric and geometric corrections.

14. Factors contributing to radiometric distortion include the following: (a) intermittent loss of data (transmission errors, synchronization loss, etc.); (b) noise (bit drops); (c) non-linear sensor response; (d) sensor miscalibration. Average adjacent lines, histogram normalization and noise filtering are examples of methods commonly used to achieve correction of radiometric distortions.

15. Geometric errors are introduced into observed data in three major ways: (a) systematic (aspects, non-linear mirror, etc.); (b) predictable (roll, pitch, yaw, altitude, etc.); (c) random (measurement error, relief displacements, etc.). Spatial location transformation, such as modelling distortions from spacecraft ephemeris and empirical approximation using ground control points and resampling are the methods used for the correction of these geometric errors.

2. Image enhancement

16. To improve image interpretation, "enhancement" techniques are used which amplify positive spectral or spatial characteristics while suppressing non-essential characteristics or redundancy. Enhancement should be designed to improve imagery for specific interpretation purposes. It must be noted that improvement of the image for specific interpretation often makes interpretation of other features more difficult. Another important factor in enhancement is the characteristics of human "sense". For example, most people can detect more shades of green than shades of blue.

17. There are several categories of enhancement, e.g., contrast enhancement, spatial enhancement, arithmetic combination, spectral transformation. Each is usually undertaken for different purposes. For instance, to exaggerate the edges between contrasting cover types, a spatial enhancement method, which adjusts the brightness value of each pixel, may be taken in order to exaggerate the difference between a pixel and its neighbours.

3. Image classification

18. Multispectral classification is used for the reduction of data into desired information classes. This technique is based on the premise that each category of interest is spectrally unique. Classification includes the following four steps:

(a) Training: developing statistics that describe the spectral characteristics of the features to be classified; training the classifier to recognize spectral statistics;

(b) Classification: assigning multispectral pixels using the classifier into spectral categories based on training statistics;

(c) Spectral class labelling: assigning spectral categories to information classes;

(d) Post-classification refinement: resolving spectral confusion and other problems.

19. There are three types of training: supervised, unsupervised and a mixture of the two. Supervised training is done by individual measurement of the multispectral characteristics of each class of interest, while unsupervised training is executed automatically using random or systematic methods. These three methods differ with respect to cost and accuracy.

4. Output devices

20. Three types of output devices are used for images or map-type products, namely, vector pen plotters, colour raster inkjet or electrostatic plotters and printing/raster film plotters. Owing to the need to produce high-volume raster data, various kinds of raster plotters are in use and are being developed, such as laser printers, inkjet and electrostatic printers. Since each printer has advantages and disadvantages, users should compare the features of these printers and select the one most suitable for their particular purposes.

D. Geographic Information System

21. The Geographic Information System (GIS) can be defined as "a system for entering, storing, retrieving and updating spatial information for a user's area of interest, designed to process information on demand and to present results in a format most suitable for the user's application". It consists of databases (e.g., geologic and vegetation information, climatic data, administrative data), hardware and software, and its basic function is to create outputs through manipulation of input data. Digital maps, remote sensing images and results of various analysis are typical for a database. Hardware often includes an input device such as a scanner, a processing computer and an output device such as a printer.

22. The advantages of GIS include the following: flexibility (analysis, evaluation, revision, updating); timeliness; potential for rapid analysis and dissemination; consistency; potential for significant enhancement; secure data for future use.

E. Example of applications of remote sensing and GIS

23. Remote sensing technology and GIS are applied in various fields. Satellites can provide data of a wide area; it is almost impossible for this to be done by a ground station network. The ability of satellites to observe the Earth globally, repeatedly and with the same instruments is of crucial value for environmental monitoring and assessment. The following examples of applications were discussed in the course.

24. United States AVHRR dataset. A dataset was developed for the conterminous United States containing 1 km AVHRR and greenness data for biweekly composites through the 1990 growing season. The data were made available on CD-ROM and were used throughout the course.

25. Topographic and hydrologic applications. Software was created to extract topographic structure and delineate watersheds and overland flow paths from digital elevation models (DEM). DEM were integrated with flow direction and flow accumulation data sets in the GIS database.

26. Greenness mapping in Africa. For the monitoring of site-specific dynamic vegetation conditions associated with grasshopper and locust breeding, vegetation index data obtained by NOAA satellites were integrated in a GIS with digital cartographic data of individual countries to provide near real-time image maps in the late 1980s.

27. Operational environmental satellite remote sensing for food security and locust control. For real/near real-time precipitation and vegetation assessment in Africa, the Near East and South-West Asia, an operational satellite environmental monitoring system, ARTEMIS, was implemented by the Food and Agriculture Organization of the United Nations (FAO), in cooperation with the NASA Goddard Space Flight Center, the National Aerospace Laboratory

of the Netherlands and the universities of Reading and Bristol. The system utilizes integrated high-frequency Meteosat data and NOAA AVHRR data. A satellite telecommunication system called DIANA is being developed by the European Space Agency (ESA) in cooperation with FAO; this would permit near real-time transmission of high-volume ARTEMIS digital data products to microcomputer-based terminals.

28. Participants were also introduced to the meteorological application of remote sensing, including an actual and accurate weather forecast for their field trip.

F. Team projects

29. All the participants were divided into six groups, each consisting of experts in different areas; the groups were thus basically multidisciplinary teams. Each was provided with a personal computer and satellite images. On the basis of the interests of its members, every group selected a problem it would address in the Black Hills area of South Dakota and worked on that problem using GIS, satellite images and a personal computer. Team projects were organized to maximize participants' initiative; these projects included practical uses of GIS, remote sensing imageries and the field trip for gathering ground truth for subsequent verification.

1. Themes of team projects

30. The themes of the team projects were the following:

Group 1: assessment of relations between geology, slope and land use in the Spearfish area using LANDSAT TM images;

Group 2: study of the seasonal vegetation types in South Dakota using the Normalized Difference Vegetation Index (NDVI) computed from AVHRR data;

Group 3: Rapid City land use update;

Group 4: land use mapping of Rapid City;

Group 5: revision of the land use classification of Spearfish using recent LANDSAT TM data;

Group 6: vegetation/rock discrimination using TM images in the Rapid City area.

2. Field trip

31. The participants went on a five-day field trip around the Black Hills, in the most eastern extension of the Rocky Mountains, in order to collect in situ data for the analysis and verification of the team projects. During the field trip, the participants were introduced to various kinds of geologic, geographic and vegetation features as well as human activities in the area, along with satellite images and GIS outputs.

32. The Black Hills constitute one of the oldest regions of the North American continent and are a classic example of "up-doming" mountain formation. A complete sequence of rock strata is found around the Hills and the area is of great geological significance. It covers nearly 6,000 square miles and rises about 3,000 to 4,000 feet above the surrounding plains, with the highest peak standing at 7,242 feet above sea level.

33. Four vegetational complexes are prominent in the Black Hills: a Rocky Mountain coniferous forest complex dominated by ponderosa pine; a northern coniferous forest complex consisting of white spruce; the grassland complex of the northern Great Plains; and a deciduous forest complex. The participants surveyed these complexes and compared their respective features on the satellite images of the area. A major forest fire had occurred in the south-eastern part of the Black Hills three years earlier and had burnt an area of almost 200 sq km. Changes in the vegetation caused by the fire were shown to the participants in situ, in comparison with satellite images of the area.

34. Participants also visited the Badlands, a rugged, eroded terrain dissected by numerous gullies and arroyos. The distinctive features of the Badlands are easily located on satellite images.

3. Experience in team projects

35. After the field trip, teams worked on finishing their studies by combining classroom work and their experience from the field trip. Each team was given 30 minutes to present its work to the other participants and instructors and discuss the results. Through their work on team projects the participants experienced a multidisciplinary approach to solving problems and gained knowledge in the practical use of image analysis based upon their own initiatives.

II. EVALUATION OF THE TRAINING COURSE

36. At the conclusion of the course, the participants were asked to complete a questionnaire on the various aspects of the content and organization of the course, including the time allotted to the topics and practical hands-on exercises of digital processing as well as the level of the subjects covered.

37. The participants expressed the opinion that the general organization and the planning of the presentations were of high quality. Depending on their experience and field of expertise, participants felt that certain topics should have been presented in greater detail. As a whole, and based on the variety of the expertise among the participants, many of them expressed the opinion that the basic fundamentals of remote sensing, digital data processing and GIS should be discussed further. It was also pointed out that the practical exercises and the field trip to evaluate the analysis was indispensable for this kind of training and it would have been more effective if there had been more computers and time allocated for that purpose.

38. The participants were unanimous in expressing their appreciation to the Government of the United States of America and to the United Nations for having organized the course. In particular, the participants highly appreciated the hospitality and devotion of the staff of the EROS Data Center. The participants also expressed their strong desire that this kind of training course should be continued.

39. The quality of the participants and their eagerness to obtain further knowledge of remote sensing, combined with the sincere effort of the instructors, contributed to the success of the course. The participants appealed to the United Nations to continue to provide this kind of training opportunity and to explore the possibility of a continuous long-term education programme in this rapidly advancing technology.

Annex

PROGRAMME OF THE COURSE

Date	Time	Subject	Speaker
Monday, 9 September	9-11 a.m.	Welcome	Adigun A. Abiodun (United Nations) Donald T. Lauer (USGS)
	1-4.30 p.m.	Review of remote sensing fundamentals Electromagnetic spectrum Present and proposed sensors	C. Trautwein (USGS)
Tuesday, 10 September	9 a.m.-noon	Fundamentals of image processing Digital image characteristics Geometric and radiometric corrections Image processing	C. Trautwein
	1-4.30 p.m.	Tour of EROS Data Center	C. Trautwein
Wednesday, 11 September	8-11 a.m.	Introduction to digital processing Overview of hardware/software Introduction to PCs Digital databases available Local and wide-area networks	 D. Greenlee (USGS) D. Greenlee F. Waltz (USGS) F. Waltz
	1-4.30 p.m.	Introduction to Black Hills Database (form teams)	J. Pursall (USGS)
Thursday, 12 September	8-11 a.m.	Image enhancement Spectral (e.g., contrast enhance) Spatial (e.g., edge enhance)	D. Greenlee
	1-4.30 p.m.	Spectral transforms Band ratios, principal components	C. Trautwein
Friday, 13 September	8-11 a.m.	Digital image classification Decision rules Supervised/unsupervised Development of training statistics Post-classification refinement	D. Ohlen (USGS) D. Ohlen D. Ohlen
	1-4.30 p.m.	Exercise (Black Hills data)	
Monday, 16 September	9 a.m.-noon	Temporal analysis Composing process Change detection	 J. Eidenshink (USGS) G. Tappan (USGS)
	1-4.30 p.m.	Applications case-studies Conterminous United States AVHRR Dataset Greenness mapping in Africa	 J. Eidenshink G. Tappan

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Date	Time	Subject	Speaker
Tuesday, 17 September	8-11 a.m.	Applications case-studies Normalized Difference Vegetation Index (NDVI) for fire fuels mapping	J. Eidenshink
	1-4.30 p.m.	Temporal analysis exercise	J. Eidenshink
Wednesday, 18 September	8-11 a.m.	Introduction to Geographic Information Systems (GIS)	N. Bliss (USGS)
	1-3 p.m.	Spatial analysis techniques	N. Bliss
	3-4.30 p.m.	Applications case-studies Soils Database (NATSGO/STATSGO)	N. Bliss
Thursday, 19 September	8-11 a.m.	Topographic analysis Derive slope, aspect, shaded relief Extract basins and drainage	S. Jenson (USGS)
	1-2 p.m.	Applications case-studies Hydrologic applications	S. Jenson
	2-4.30 p.m.	Topographic analysis exercise	S. Jenson
Friday, 20 September	8-11 a.m.	NGDC global diskette project	J. Kineman (NOAA)
	1-4.30 p.m	Climatology applications Hydrologic, marine and atmospheric applications	K. Gallo (NOAA)
Monday, 23 September	8-11 a.m.	Output products and data presentation	J. Hutchinson (USGS)
	1-4.30 p.m.	Demonstration	J. Hutchinson
Tuesday, 24 September	8-11 a.m.	Team projects - work on PC datasets	Staff
	1-4.30 p.m	Work on PC datasets	Staff
Wednesday, 25 September	8-11 a.m.	Work on PC datasets	Staff
	1-3.30 p.m.	Work on PC datasets	Staff
Thursday, 26 September	8-10 a.m.	Work on PC datasets	Staff
	10 a.m.-noon	National Weather Service briefing	G. Harmon (NOAA)
Friday, 27 September	8 a.m.-6 p.m.	Field trip (Badlands National Park)	Staff

Date	Time	Subject	Speaker
Saturday, 28 September	8 a.m.-6 p.m.	Field trip (Black Hills National Park)	Staff
Sunday, 29 September	8 a.m.-6 p.m.	Field trip (Black Hills National Park)	Staff
Monday, 30 September	8 a.m.-6 p.m.	Field trip (Black Hills National Park)	Staff
Tuesday, 1 October	8 a.m.-4 p.m.	Field trip (return to Sioux Falls)	Staff
Wednesday, 2 October	8 a.m.-noon	Preparation of student presentations	Staff
	1-4 p.m.	Student presentations and discussion	Staff
Thursday, 3 October	9-11 a.m.	Operational environmental satellite remote sensing and information dissemination for food security and locust control by FAO	Jelle Hielkema (FAO)
Friday, 4 October	9-11 a.m.	Closing ceremony	

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COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

APPLICATIONS OF BIOMEDICAL TECHNOLOGY RESULTING FROM SPACE LIFE-SCIENCE RESEARCH

Study by the Secretariat

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BACKGROUND

1. The Scientific and Technical Subcommittee, in the report on the work of its twenty-eighth session (A/AC.105/483, para. 80), recommended that the Secretariat prepare a study of medical technology that had resulted from research in space, based on information compiled from existing sources and information submitted by Member States, and of the ways and means to implement the General Assembly recommendation on the matter, as contained in paragraph 8 of Assembly resolution 45/72 of 11 December 1990.

2. The General Assembly, in resolution 45/72, endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space that the Subcommittee should consider, on a priority basis, the implementation of the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82). In that context, the Assembly, in paragraph 8, considered it particularly urgent to implement the recommendation that all countries should have the opportunity to use the techniques resulting from medical studies in space.

3. The present study has been prepared by the Secretariat in response to the above recommendation of the General Assembly. Its purpose is to review the biological and medical research that has been undertaken in space and to examine its actual and prospective applications in terrestrial medicine and health care. The study is intended primarily for the benefit of countries that have not yet undertaken this kind of research but are interested in its potential benefits.

4. The present study is based in part on previous United Nations documents containing information on space life-science research and medical applications. The Working Group of the Whole to Evaluate the Implementation of the Recommendations of UNISPACE 82, at its third session, in 1989, recommended that the Committee invite Member States to report annually on techniques resulting from medical studies carried out in outer space (A/AC.105/429, annex II, para. 5 (a)), and that recommendation was endorsed by the Committee. 1/ Information on this subject has been reported by Member States and is contained in the report on international cooperation in the peaceful uses of outer space - programmes of Member States (A/AC.105/448 and Add.1-3) and in the reviews of national and international space activities (A/AC.105/458 and A/AC.105/470 and Add.1 and 2). Information on space life-science research and medical applications has also been presented to the Scientific and Technical Subcommittee through special technical presentations arranged by Member States. Summaries of those presentations are contained in documents A/AC.105/459 and A/AC.105/487. The information from those previous reports has been used in preparing the present report.

5. Information on space life-science research and biomedical applications is also contained in a variety of reports from national and international space agencies and in books and articles, and such sources have been used in preparing the present report (see references).

I. SPACE LIFE-SCIENCE RESEARCH

A. Special conditions of space flight

6. Since the beginning of the space age there have been rapid developments in space biology and medicine, due primarily to the need to ensure the survival of space crews and to enable them to work under conditions of weightlessness. This challenge was posed for the first time in 1961 when Yuri Gagarin orbited the Earth, and more than 250 individuals have since been launched into space for various lengths of time, including visits to the surface of the Moon. With the increasing length of space flights and complexity of space activities, the problems of space biology and medicine have also become increasingly complex. For long-duration space flights, it has been found that an elaborate physiological support system is necessary to limit health problems arising from readaptation to gravity upon return to Earth.

7. While the priority of space medicine has been to protect the health of crews in space, the space environment also provides unique research opportunities for the life sciences. On Earth, the anatomy and physiology of all living organisms are affected by, and adapted to, the constant force of gravity. Space flight provides opportunities to study the effects of gravity through experiments under conditions of weightlessness. While some of the effects of weightlessness can be simulated on the ground, the absence of gravity cannot be simulated. In addition, since the Earth's atmosphere and magnetic field largely protect life from the effects of the high-energy subatomic particles of cosmic radiation, space-flight provides an opportunity for studying the effects of such radiation on organisms.

8. The practical constraints of space flight often require technological innovations to ensure adequate medical facilities for space crews. In particular, space instruments or systems need to be compact, lightweight, easy to use and highly reliable, and meeting these requirements often calls for innovation in design and materials. Those instruments can then find their way into Earth-based laboratories, hospitals and clinics as new research, diagnostic and therapeutic tools for dealing with terrestrial medical problems.

9. All crewed space flights have included medical monitoring, and most have included physiological experiments. The Union of Soviet Socialist Republics Salyut and Mir space stations and the United States Skylab missions provided opportunities for extensive space physiological studies, and the United States, the European Space Agency (ESA) and Germany have collaborated on Spacelab missions including intensive physiological and biological experiments. Planning and development work are now under way for the International Space Station Freedom, which will have extensive facilities for long-duration physiological and biological research. As part of that programme, the European Columbus system will include Biolab and Anthrolab facilities for life-science research.

10. Life-support systems for spacecraft require a certain amount of processing and recycling of physiological waste products. While the requirements are quite modest for short-duration space flights and for spacecraft which can be regularly resupplied in Earth orbit, the recycling requirements will be much greater for future long-term crewed missions such as lunar bases and interplanetary missions. Long-duration crewed space missions in Earth orbit provide an essential means for studying and testing systems and methods for more extensive recycling for maintaining the water supply, the atmosphere and the food supply. Such recycling technologies also have applications on Earth, particularly under such special conditions, such as deep underground mines, expeditions to the polar regions, mountains and deserts, underwater facilities and ultra-clean research laboratories, as well as for improving environmental conditions in more ordinary circumstances.

11. Special medical monitoring and diagnostic instruments for space flight are required not just on board the spacecraft, but also on the ground for training before the flight and for monitoring the condition of crews after landing. In addition, a back-up crew is usually studied simultaneously on the ground to allow comparison of conditions of the crew with others who have undergone the same preparation. In case of a medical emergency in space, these ground facilities can be used to test possible responses using facilities identical to those on board the spacecraft. The use of these space facilities and instruments on the ground, and the larger number of people who use them, can facilitate transfer of space technology to ordinary medical applications.

12. Because the spacecraft size is severely constrained by launching capabilities, crews have very limited space for working, eating, sleeping and other activities and few facilities for relaxation and entertainment. The requirements for living in very close quarters with other people, especially on long-duration flights, may pose special psychological problems. Psychological testing for the selection and monitoring of space crews has been carried out for all of the crewed space missions. As part of the USSR space station programme, for example, Czechoslovak psychologists have used voice analysis to study psychological stress on space crews, and Bulgarian researchers have studied neurological activities during sleep under conditions of space flight. In general, however, the available information on the scientific results of psychological tests and on the applications of that knowledge is very limited, and the present study will focus on biological and physiological results and applications.

13. The presence of crews on spacecraft is not always necessary for space life-science research. In fact, small "free-flyer" automated satellites with recoverable capsules have the advantage of being comparatively cheap, easier to launch and recover, and more flexible in flight duration. They are therefore attractive for biological experiments that do not involve human subjects and do not require human tending. The USSR Biocosmos series of satellites with recoverable capsules, beginning in the 1970s, provided opportunities for international collaboration on space life-science research. More advanced automatic research platforms are in the planning stages, including the United States Lifesat and the German Raumkurier spacecraft.

14. The special conditions and requirements of space flight have therefore given rise to a variety of new knowledge, new instruments and new procedures for use both in space and in ordinary medical research, diagnosis and treatment. In some cases, such as knowledge of the effects of gravity, the new knowledge might not have been discovered without space flight, while in other cases space research accelerated the development of the new capabilities.

B. Biological effects of gravity

15. While an orbit a few hundred kilometres above the Earth's surface is not outside the influence of the Earth's gravity, a spacecraft orbiting the Earth without propulsion moves in a circular or elliptical trajectory with an acceleration that counteracts the force of gravity on the spacecraft and its contents. The effect is in principle the same as that of free fall during a suborbital sounding rocket flight or parabolic unpowered aircraft trajectory which can provide conditions of weightlessness for periods of up to a few minutes.

16. Strictly speaking, a spacecraft, particularly one with an active crew, is subject to a variety of small vibrations and other accelerations, so the conditions on board are not those of perfect weightlessness. For this reason, the practical conditions on board spacecraft are technically referred to as microgravity. Crew activity typically creates accelerations on the order of 1/10,000 to 1/1,000 of the acceleration due to gravity at the Earth's surface, an effect which would not be noticeable to the crew but which can affect the results of certain gravity-sensitive experiments. Higher accelerations occur during orbital manoeuvres using small thruster jets, and lower accelerations can be achieved on automatic satellites with no moving parts. For the purposes of the present report, the term "weightlessness" will be used where the accelerations are insignificant relative to the phenomenon being studied.

17. Research during crewed space flight, on automated biological satellites and in ground-based experiments modelling the effects of weightlessness have provided much information concerning the nature of the effects of the gravity on various biological subjects, including humans, under normal and pathological conditions. Space medicine has broadened our understanding of the mechanisms of human spatial orientation, the structure and function of the vestibular apparatus, postural motor reflexes, biomechanics, the motor apparatus of the body, the cardiovascular and nervous systems and the mechanisms for the maintenance of normal physiological conditions.

18. Data collected during space flights have demonstrated that humans and other organisms undergo profound but apparently reversible physiological changes under conditions of weightlessness. These changes occur during two phases: an acute phase during the first hours and days in space; and an adaptive phase, which may take many days or weeks. The major changes can be grouped in three areas: the shift of blood from the lower part of the body to the upper; the inactivity or unloading of muscle and bone; and disturbances caused by unfamiliar sensory inputs.

19. An example of a disturbance caused by unfamiliar sensory inputs is the phenomenon called space motion sickness. It is a neurophysiological problem resulting from conflicting signals sent by the otoliths (balancing organs of the inner ear), the eyes and muscle sensors. Under conditions of weightlessness, the eyes may tell the brain that the body is motionless, while the inner ear is signalling the brain that the body is falling.

20. Research has revealed that the gravity-sensing cells in mammals act as parallel processors, processing information from different sources simultaneously, resulting in disturbances when the information from the different sources is in conflict. It has also been determined that the gravity-sensing cells in mammals form a "weighted neural network", where the number of connections for each neural pathway is as important as the actual pathways for the information. The brain itself is also a weighted neural network, but its enormous complexity makes it a very difficult subject for study. The gravity-sensing cells offer a much simpler natural neural network to study, offering insights not only into the workings of more complex systems such as the brain, but for the development of parallel-processing computer systems for "artificial intelligence".

21. The problem of adaptation to weightlessness in space is similar to the problems encountered by patients whose severe illnesses or injuries necessitate long-term bedrest or other immobilization. Patients lying in bed for long periods experience muscle atrophy due to the "unloading" of postural muscles, and the head-down tilt used in space-related bedrest research mimics the headward fluid shift that occurs in weightlessness. Studies of long-term bedrest sponsored by the United States National Aeronautics and Space Administration (NASA) and other biomedical investigations of physiological deconditioning are providing information on pharmaceutical and other treatments for bone and muscle deterioration.

22. One NASA research project has measured significant muscle weakness and deterioration during seven days of bedrest. Changes in the rates of protein breakdown and synthesis were also observed, and insulin-stimulated glucose use was found to decrease significantly. Those experiments demonstrated that relatively short experiments can be used to study the effects of long-term immobilization and of treatments to counter the harmful effects of immobilization.

23. Experimental subjects confined to bed were given exercise programmes designed to keep them at normal fitness levels despite their immobility. NASA investigations conducted during 30 days of bedrest found clear beneficial effects of the exercise. Certain exercise programmes were found to maintain muscle strength, while others maintained physical work capacity. Exercise did not, however, improve the subjects' ability to walk or stand unimpaired immediately after the period of bedrest ended, suggesting that countermeasures other than exercise may be required to solve this problem. The results of these experiments appear to be applicable to both the problems of clinical long-term bedrest and the problems of deconditioning due to weightlessness.

24. Another method for ground-based study of some of the physiological effects of weightlessness is the use of water immersion for a few hours or days, using the water tanks that are also used for the training of space crews. This method has been used, for example, for research sponsored by the French Centre National D'études Spatiales (CNES). Ground studies simulating some of the effects of weightlessness and studying ways to counteract those effects have also been undertaken by the Soviet Union. Efforts are being made to standardize the experimental procedures to facilitate international comparison of results.

25. While some of the physiological responses that occur during space flight can be produced by bedrest or water immersion, neither technique can fully simulate weightlessness, since the relative densities of the various parts of the body still respond to the force of gravity. At the level of the inner ear, for example, the otoliths still exert their action on the sensory cells, so that space motion sickness effects cannot be studied in this way. Furthermore, the duration of these ground experiments, particularly in the case of water immersion, is limited by practical constraints and cannot equal that of long-duration space missions.

C. Space radiation biology

26. The other special characteristic of space, in addition to weightlessness, is the presence of cosmic radiation, consisting of protons, alpha particles and heavier ions and atomic nuclei. While some cosmic radiation reaches the ground, most is shielded by the atmosphere, so that the intensity in space may be 200 times greater in low Earth orbit and even higher at greater altitudes or on interplanetary missions. While proton radiation predominates on missions in low-Earth orbit, heavier particles contribute significantly to the radiation environment in deep space and would constitute an important health hazard for interplanetary flights. The biological effects of cosmic radiation are due to the dense ionization along particle tracks, which may traverse a considerable number of cells. It is therefore essential to understand both the short- and the long-term biological effects of heavy charged particles in order to estimate the risks of prolonged stays in space.

27. The intensity of cosmic radiation is quite variable, largely due to variations in particles from the sun. Intense solar flares can cause an increase in cosmic ray intensity that would threaten the health of crews in space. Efforts to monitor cosmic radiation and to develop and test new monitoring instruments have therefore been carried out during space missions conducted by the USSR, the United States and on international missions. For example, in 1990, an instrument designed to measure the intensity of cosmic radiation as a function of the energy of the particles and their biological effectiveness was tested on the 13-day Cosmos 1887 Biosatellite mission, involving the participation of scientists from Czechoslovakia, France, Germany, the Netherlands, the United States and the USSR.

28. Living organisms on Earth that are continuously exposed to very low radiation levels from a wide range of natural and artificial sources are normally able to repair or replace the damaged cells. When exposure to high radiation doses destroys a large number of cells in a short time, however, the natural repair processes can be disrupted, overwhelmed or altered. Such circumstances are particularly serious when those cells are located in vital areas such as blood-forming organs and the gastro-intestinal tract.

29. Some parts of the body are more vulnerable to radiation damage than others. The skin and eyes, for example, suffer greater exposure to particles with limited penetration capabilities, but are less sensitive to radiation damage. Certain deeper locations, including the bone marrow, lungs, pancreas and liver, are less exposed to radiation but are more sensitive, and the damage may have greater effects on overall health. The susceptibility of breast tissue to radiation-induced cancer means that women face added risks. The reproductive system is also susceptible to damage, but that process is not yet well understood.

30. The overt symptoms of radiation damage can be immediate or delayed. Near-term manifestations of intense exposure can include nausea, vomiting, decreased white blood cells, diarrhoea, fever, haemorrhage and death. Delayed effects include cancer, miscarriages and birth defects in progeny.

31. While the effects of long-term exposure to heavy-particle radiation can only be practically studied in space, short-duration exposure has been studied on the ground using particle accelerators at Darmstadt (Germany), Dubna (Russia) and Berkeley (United States). Those studies have examined the effects of high-energy heavy ions in order to improve the design of spacecraft shielding. The studies have examined the effects of heavy charged particles, including damage to DNA, genetic mutations, malignant transformations, the induction of cataracts, changes in animal behaviour, changes in the biochemical activities of the brain and reductions in life expectancy.

32. Studies of the long-term effects of cosmic radiation were conducted on the United States Long Duration Exposure Facility (LDEF) satellite, which carried biological samples such as spores, seeds and shrimp cysts and exposed them to cosmic radiation for nearly six years. Some of the experiments allowed localization of the trajectories of single particles through layers of biological materials. One of the experiments involved exposure of a large number of tomato seeds, and samples of those seeds have been distributed to schools to involve schoolchildren in space biology experiments.

33. The results of cosmic radiation studies not only are useful for protecting future space crews from the harmful effects of radiation, but can also be applied to radiation protection on Earth, particularly to ensure the radiation safety of personnel working with or near hazardous radioactive materials.

34. While cosmic radiation clearly has an effect in space, as it does on the ground, there also appears to be an interaction between sensitivity to

radiation and microgravity. Recent studies have indicated that exposure to heavy charged particles and microgravity can act synergistically on the eggs of a simple organism and can result in developmental anomalies. Further studies are needed to provide a sound understanding of this interaction.

II. ENVIRONMENTAL HEALTH APPLICATIONS

A. Environmental control and waste recycling

35. If people are to spend long periods living and working in the restricted and artificial conditions of space facilities, extensive efforts are required to maintain a healthy environment. Supplies of good food, water and air need to be continuously provided, waste products must be disposed of and microbiological, toxicological and radiological conditions must be rigorously monitored and controlled. Work on the development of life-support facilities for spacecraft has led to scientific and technical knowledge which can be used to ensure a healthy living and working environment for people not only in space, but also at home and in the working conditions of modern industry.

36. Research in the USSR resulted in the development of the Ikar instrument for automatic measurement of up to 40 different organic impurities in air, including acetone, benzene, butanol, xylene, toluene and formaldehyde. The detection threshold is two to three orders of magnitude lower than with standard chromatographs, and a complete analysis takes less than an hour. The equipment weighs about 64 kg. Such technology is becoming increasingly important on Earth as buildings are made increasingly airtight in order to conserve energy. As a result, potentially toxic vapours from construction materials and furnishings can build up if they are not monitored and eliminated.

37. An electrochemical analyser for measuring the purity of water or other liquid media by the absorption of impurities on a platinum micro-electrode was also developed in the USSR as a result of space research. It can be used to determine micro-quantities of heavy metals and organic impurities in water to determine if it is safe for drinking or for other uses. The instrument is extremely sensitive and requires only 5 to 10 minutes for an analysis.

38. Both crewed spacecraft and interplanetary probes require testing for disease-causing microorganisms. For the Voyager space missions, a Microbial Load Monitor was developed in the United States to detect bacterial contamination on spacecraft. That space technology was subsequently converted into a time-saving system for analysing a patient's body fluid samples for the presence of microorganisms. The resulting commercial AutoMicrobic System can reduce hospitalization by allowing quicker and more efficient identification and earlier treatment of an infection. The traditional method of identifying human pathogens and determining an effective treatment takes from two to four days. The AutoMicrobic System does the same job 50 to 80 per cent faster, minimizes human error, reduces technician time and increases laboratory output.

39. Recent research on spacecraft life-support systems has focused on the recycling of waste products to regenerate drinkable water, breatheable air and, ultimately, nutritious food. The research considers a spacecraft an ecological system, including humans, plants, animals and microbial organisms. Scientists in Canada, Czechoslovakia, France, Germany, Japan, the USSR, the United States and other countries have been studying techniques for recycling waste products within ecological systems that require a minimum of external supplies.

40. The NASA Controlled Ecological Life Support System (CELSS) programme was initiated in 1978 to study ways to improve existing space life-support systems so that they could support long-duration missions. The central feature of CELSS is the use of green plant photosynthesis to produce food and oxygen, while removing carbon dioxide. In research along the same lines in Czechoslovakia, biologists working in cooperation with the USSR space programme have studied the growth of chlorella algae in space in an effort to determine the optimum conditions for a sustained high rate of growth.

41. Results from NASA studies of plant growth under controlled conditions indicate that plants commonly grown as agricultural crops have a much greater productivity potential than is currently realized in field conditions. Although some growth stimulating techniques, such as enriching a closed atmosphere in carbon dioxide, may not apply in the open field, other techniques may be applicable to ordinary agriculture. The design of small, efficient plant growth chambers may have practical value in urban areas, in regions where growing conditions are not suitable for particular crops or in extreme environments such as the Antarctic or deserts.

42. For extraterrestrial bases, on the Moon or Mars for example, virtually complete recycling of waste products would be required. More speculative studies are also under way on the possibility of long-term transformation of the present inhospitable environmental conditions on Venus or Mars, using "terraforming" strategies involving microorganisms to gradually transform the atmospheric conditions. Such studies are closely related to theories of the evolution of the Earth's environment, both in the past in response to natural evolution, and in the future in response to human-induced environmental changes.

B. Ecological monitoring for public health

43. A variety of diseases are spread by insects or other organisms that thrive under specific ecological conditions. Data from remote sensing and meteorological satellites can provide information on the timing and location of potential outbreaks of such diseases, allowing timely intervention. Other environmental factors such as the ozone layer and air and water pollution also have important effects on people's health and can be observed from space.

44. Over half the world's population - 3.2 billion people - currently live in areas where malaria is common, and over 100 million new cases of malaria occur

every year. Predicting the time and place of mosquito outbreaks is the key to the control of malaria epidemics. NASA is using remote sensing technology to identify the habitats in which mosquitoes can breed and the timing of increases in mosquito population before they occur. Reliable predictions of mosquito populations based on remote sensing data can be used to treat the breeding areas before the mosquito larvae turn into carriers of malarial parasites and other disease agents.

45. Based on the results of such experiments, a project for a specialized "MedSat" remote sensing satellite is in the feasibility study stage. This satellite would be equipped with special multispectral and radar imaging sensors as well as data processing and communications subsystems.

III. MEDICAL APPLICATIONS

A. Cardiovascular function and heart disease

46. Since circulation is a vital function that is substantially affected by the weightless conditions in orbiting spacecraft, it has been a major focus of medical studies in space since the beginning of human space flight. In view of the fact that cardiovascular disorders are a major cause of illness and death on Earth, space research has had greater practical applications for such disorders than in other areas of medicine. Countermeasures developed for circulatory changes in space may be of benefit in combating cardiovascular illness, muscle deterioration and other types of physiological deconditioning on the ground. NASA's Extended Duration Orbiter Medical Program is working to develop and verify procedures and countermeasures designated to optimize crew performance on longer-duration Shuttle missions. Exercise equipment for this purpose must be efficient, quiet, low-vibration and portable. In addition, exercises must provide maximum conditioning in a minimum period of time. Such equipment and techniques could be of great benefit in the treatment and prevention of cardiovascular disease by encouraging greater physical fitness.

47. Heart disease is the leading cause of death in many industrialized countries. When the control system regulating the periodic contraction of heart muscles malfunctions, a pacemaker can be used to generate a life-saving electrical pulse that regulates the contractions. Early pacemakers were developed through NASA programmes using miniature electronic circuit technology. In 1979, a programable pacemaker was introduced, and now a system with two-way communications capability has been developed based on NASA space communications technologies. This new system allows a physician to communicate with a patient's pacemaker using radio telemetry, so that instead of the previous fixed stimulus the regulating stimulus can be fine-tuned to meet each patient's individual needs.

48. People who survive a heart attack are still quite likely to die during the next year due to ventricular fibrillation. An Automatic Implantable Cardioverter-Defibrillator, recently developed using United States space technology, offers a solution to this problem. The system, which is

surgically implanted, detects fibrillation and automatically delivers a balanced electric pulse to restore normal heart rhythm. Through telemetry, the device can be interrogated to determine if a defibrillating pulse has been provided, and, if so, to look at the electrocardiogram just before and after the episode. This product has been privately commercialized. An advanced portable defibrillator can be used in emergency situations to revive heart attack victims on the spot.

49. One technology resulting from aerospace research that may some day eliminate or significantly reduce the need for coronary bypass surgery is the combined use of lasers and fibre optics. Physicians and NASA scientists jointly developed a laser system to non-surgically clean clogged arteries with high precision. The procedure, which is still in the experimental stage, involves threading a 1.5 millimetre diameter catheter through coronary arteries. The laser light is carried through one of the three optical fibres within the flexible catheter. Watching the video pictures fed through the other fibres, the physician can spot areas of plaque build-up in the artery and vaporize or disintegrate the plaque with short bursts of intense laser light. The process occurs so quickly that neighbouring tissue is spared from damage.

50. An instrument for monitoring blood pressure was developed for use on the Spacelab mission dedicated to life-science research in order to study the capability of the cardiovascular system to control blood pressure so as to maintain an adequate supply of blood to the brain. An inadequate supply often results from disturbances of normal blood pressure regulating mechanisms during and after space flight. A commercial version of this instrument is now available in the United States under the name Baro-Cuff. It is being used to monitor the regulation of blood pressure in patients with congestive heart failure, chronic diabetes mellitus, hypertension and other conditions involving problems in maintaining blood pressure. The system is also being used in medical schools for clinical investigations and by researchers in the field of cardiovascular physiology.

51. Under normal terrestrial conditions, cardiopulmonary resuscitation (CPR) involves repeated applications of force to the patient's chest while ventilating the lungs. In space, however, both patient and rescuers are floating free, so that rescuers cannot easily perform standard CPR. This problem has been overcome by securing the patient on a table-like restraint, with the rescuer held in place over the patient with a simple harness attached to the restraint. The harness prevents the recoil force of the chest compressions from propelling the rescuer away from the patient, thus permitting sustained and effective CPR. Another method utilizes a lever-arm device which attaches to the side of the patient restraint. A smoothed rectangular block attached to the lever is placed on the patient's sternum, and chest compression can be easily applied through modest force on the end of the lever. Both methods have been tested successfully using CPR manikins in simulated weightlessness on aircraft.

52. NASA is also conducting research on other emergency cardiac treatment methods, including a pneumatic vest that could be inflated quickly to provide a sharp increase in thoracic pressure automatically. Once fully developed and tested, devices such as these could be incorporated into an emergency medical package for use in space and could also lead to improved CPR techniques on Earth.

53. In the USSR, the Argument instrument was developed to scan the heart and major blood vessels by means of ultrasound in order to observe the condition of its chambers and the major blood vessels, as well as the functioning of the valves and cardiac muscle. This portable instrument can be used for specialized diagnosis of cardiovascular diseases in clinics and ambulances. French researchers have performed similar "echography" experiments to study the behaviour of the circulatory system of French astronauts during their flights on USSR and United States spacecraft. The French "Ace of Hearts" echography instrument is a compact circulatory-monitoring device consisting of a number of different sensors, a video monitor, a miniature video recorder, a keyboard and a power supply. French medical scientists also developed a Minilab for performing biochemical and hormonal analyses of blood and urine samples during space flight.

54. The Ekhovazoskop instrument was developed in the USSR for measuring and recording blood flow in organs, with real-time display of the observations on a cathode-ray screen and digital display. The instrument can be used in experimental medicine and in neurosurgery for monitoring blood flow and fluid dynamics in the brain, in other organs and in the main blood vessels. Since the instrument is portable, it can also be used in ambulances.

55. A transportable artificial kidney was developed in the USSR and approved for people suffering from endogenous and exogenous poisoning or from diseases of the kidneys or liver, and for liver transplant operations. Special circuits for purification of the dialysate prevent the removal of inorganic substances from the body. This made it possible to reduce the volume of the dialytic solution from 300 to 1.5 litres and to lengthen the intervals between dialyses. This artificial kidney can be used in both clinics and ambulances and could be further developed into a portable artificial kidney.

56. A technique developed in the USSR for the purification of liquids could be used to eliminate toxins from the blood without damaging the normal components. The process involves applying a special coating to a toxin-absorbing material which makes it fully compatible with the blood. This new coating process is simple and inexpensive and does not change the absorption capacity of the material since the coating does not impede access of toxic substances to the absorbing surface. The absorbent material prepared by this method does not destroy the cellular elements of the blood, give off particles or deoxygenate the blood and may be sterilized by any means since the coating withstands heat up to 250°C without any change in properties.

B. Respiratory and metabolic monitoring

57. The respiratory and metabolic functions of space crews have also been carefully monitored to ensure the health of the crews and to study the effects of the space environment. The Pneumotest device was developed jointly by specialists from the USSR and Germany for research on the biomechanics of human respiration. The total flow of air during inhalation and exhalation, ranging from 0.15 to 20 litres per second, can be measured with an error of less than 5 per cent. The built-in microprocessor can provide readings of over 30 respiratory indicators, including respiratory volume, the vital capacity of the lungs, the inhalatory and exhalatory reserve volume and the temperature of exhaled air. In view of its portability and high reliability, it is well-suited for clinical use as well as for research. For treatment of respiratory problems, a multi-purpose portable respirator was developed in the USSR space programme for extended ventilation of the lungs, treatment of atelectasis and active inhalation of medical aerosols and anaesthetics. The device can be used in resuscitation procedures and may be a valuable piece of equipment in ambulances.

58. To study the effect of the space environment on human metabolic functions, the Plasma-02 device was developed in Czechoslovakia for the withdrawal, separation and preservation of body fluids of cosmonauts on board the Mir space station. An analysis of samples of blood taken as part of the Aragatz project during the joint Soviet-French space flight, for example, showed a significant rise in noradrenalin on the ninth day of the flight. This unit could be used on the ground to obtain samples in case of accidents in remote areas. Another Czechoslovak medical instrument, the Oximeter, was designed to determine oxygen levels in the tissue of live organisms, either human or animal. After its successful use on several international crewed space flights, a commercial version was produced for clinical use.

59. An ambulatory monitoring system developed for feedback training experiments in space enables the continuous recording of up to nine channels of physiological measurements over an 18-hour period. NASA researchers, in collaboration with university scientists, are also developing a non-invasive, computer-controlled, blood pressure monitoring system for beat-to-beat tracking of systolic and diastolic blood pressure, a device which can be used for feedback training for controlling high blood pressure.

60. Insulin-dependent diabetics have generally been tied to a rigid schedule, determined by the need for regular insulin injections. Now, some 12,000 diabetics in the United States are free from such restrictions through the use of an insulin infusion pump developed using space technology. The compact package houses a microprocessor, a long-life battery, a reservoir for the insulin, a pump and a syringe. The patient inserts the needle beneath the skin, usually in the abdomen. The small pump infuses insulin at either the "basal rate" for continuous delivery or the "bolus rate" for larger amounts of insulin administered prior to meals or when blood sugar levels are elevated. The system can be programmed with up to four basal rates, for patients whose insulin requirements change during the course of the day. In addition, research has shown that infusion of "short-acting" insulin in tiny amounts

over a long period, instead of multiple daily injections of long-acting insulin, has helped many diabetics achieve better control of blood-sugar levels, thereby minimizing the possibility of complications.

61. New biochemical sensors, very tiny instruments that can be implanted or inserted into the body of a research subject, will permit investigators to measure concentrations of ions such as calcium, sodium and potassium in real time, in space or on the ground. Changes in the concentrations of these ions during space flight can indicate physiological changes in response to weightlessness. A steady increase in calcium in the blood, for example, would probably indicate bone demineralization, while increasing concentrations of all of those ions might indicate dehydration. On the ground, changing blood concentrations of calcium or other substances following experimental ingestion or medical treatment can be monitored using such sensors.

62. In 1989, NASA entered into a joint agreement with private-sector partners for the development of an implantable calcium ion sensor to be used for biomedical investigations on space flights and in ground laboratories. The sensor is to be produced commercially for the medical community for rapid and accurate analysis of blood. Similar biosensors could also be developed for analysing urine and other fluids. If this type of sensor proves effective for biomedical analyses, it could be cheaper, faster and more convenient than the traditional method of collecting samples, storing them and sending them to a laboratory for analysis. Biosensor technology may also prove useful for on-site, real-time analysis of drinking water or waste water in the public health and environmental protection fields.

63. NASA has developed an ingestible "temperature pill" which will enable physicians to treat more accurately such emergency conditions as dangerously low or dangerously high body temperatures. The device, developed in cooperation with a university laboratory, is accurate to 0.01°C and is the only practical means of obtaining deep-body temperatures. It incorporates several aerospace technologies, such as integrated circuit miniaturization, sensor and microbattery developments, and telemetry technology. Work is proceeding on an advanced four-channel ingestible capsule that will simultaneously monitor temperature, heart rate, inner-body pressure and acidity.

64. NASA scientists have also developed a high-frequency (15 Mhz) ultrasound sensor capable of detecting the interface between non-viable burned tissue and viable tissue around burn sites with a resolution of 0.1 mm. The main cause of death among burn victims is bacterial infection, which is often exacerbated by the long time required for the spontaneous sloughing of necrotic tissue. This new instrument can minimize the time needed for determining which burns will heal naturally (partial-thickness burns) and which will require skin grafting (full-thickness burns). Clinical testing has demonstrated a 92 per cent correlation between the results obtained with this instrument and direct microscopic measurements. Work is continuing on the development of a data processing system that will convert the measurements into easily interpretable information to guide surgeons in determining the depth of injury and planning appropriate treatment.

C. Exercise and ageing

65. Some of the physiological changes that have been observed during space flight are similar to some of the effects of ageing, although unlike ageing they are reversible after return to the Earth. Research on those effects should offer an understanding of the normal process of ageing. For example, there is evidence that age-related difficulties with body equilibrium are related to changes in various organs, including the muscles, the sensory cells of the vestibular system and the joint receptors, and probably the central nervous system as well. Studies also indicate that an increase in sympathetic nervous system activity occurs as an effect of age. These parameters change in a similar way during space flight. Muscle atrophy, vestibular dysfunction and post-flight postural disequilibrium have occurred repeatedly in crewed space missions.

66. Bone demineralization during space flight can lead to weaker bones that are more susceptible to fracture, similar to the process of osteoporosis, which commonly affects the elderly. Researchers now believe that there is an uneven redistribution of calcium in weight-bearing bones during prolonged space flight. To monitor this process, NASA has developed a practical, inexpensive, non-invasive method of making quantitative measurements of bone stiffness and mass under any conditions. There are two possible approaches to the problem of bone demineralization: (i) drugs or surgical procedures to correct for the condition; or (ii) learning how to prevent demineralization from occurring. For prevention, detailed knowledge of how bone cells grow and function would be needed. Space research is being used to gather information and develop techniques relating to both of those approaches.

67. Animal and human studies of neuro-vestibular changes during space flight may provide insight into the mechanisms involved in similar age-related changes. Countermeasures developed for space flight to slow or diminish the progress of such neurological changes may eventually be applied to help the elderly to cope with such neurosensory problems.

68. The AVIMP instrument, developed in the USSR, applies a pulsed magnetic field to the body to stimulate muscles for physiotherapy and for the treatment of inflammation, edema and osteochondrosis. It is effective even when operating through clothing, gauze, plaster and other non-metallic coverings with thicknesses up to 10 mm. The instrument, weighing about 24 kg, has a wider range and a greater depth and effectiveness of operation than standard instruments, puts less pressure on surface tissue and can reduce the treatment period by one third.

D. Vision, hearing and neurological applications

69. The portable Korteks-2 instrument was developed for the joint Soviet-Cuban space flight in 1980 to study the functioning of the central nervous system and evaluate human psychophysiological functions. It records an electro-oculogram, an electrocardiogram and an electro-encephalogram using two electrode points and processes the data with a microcomputer. The

instrument could find applications in studies of visual perception and information processing under a variety of conditions.

70. In conjunction with the selection and preparation of Canadian space flight candidates, a team of scientists is conducting research on the rotation of the human eye. A slight rotation of the eye in its socket is observed as the axis of the visual field shifts; such movements may be useful in predicting which individuals will be susceptible to space motion sickness.

71. To combat motion sickness, NASA scientists have developed an autogenic feedback training procedure to help people learn to regulate their autonomous nervous system so as to prevent the symptoms of motion sickness. Plans are being developed to test the procedure on cancer patients as a possible countermeasure for nausea and vomiting caused by chemotherapy. To define more precisely the physiological changes and the accompanying sensations in motion sickness, scientists developed a pulsed infrared reflectance sensor for measuring skin blush and pallor. The device can also measure average blood volume, pulse amplitude and heart rate, and is adjustable so that it works equally well on dark- and light-skinned individuals. Hospitals should find this skin-pallor device particularly useful during surgical operations, in recovery, and in intensive care units to detect the beginning of shock, nausea, syncope and related problems. In addition, it may be useful in diagnosing Raynaud's syndrome and other circulatory disorders. It is in the process of being commercialized.

72. Many astronauts report significant back pain during flight, a phenomenon thought to result from the lengthening of the human spine under conditions of weightlessness. A Canadian team is investigating whether the range of motion of various joints, especially non-weight-bearing joints, is increased under conditions of weightlessness. This may lead to a better understanding of human adaptation to space and to better treatment methods for back-pain syndromes of patients on Earth.

73. NASA, working with a private company, has developed the Visiscreen-100, a portable device designed to detect eye problems in children through the analysis of retinal reflexes. This system incorporates NASA image-processing technology in combination with a 35 mm camera, a telephoto lens and electronic flash. The system can test the human eye for refractive error, obstruction in the cornea or lens or even ocular alignment problems. The Visiscreen-100 can be used in day-care centres to diagnose infants and pre-school children who otherwise might not be tested until school age.

74. Plastic lenses for eyeglasses typically weigh half as much as glass, can be readily shaped to conform to facial contours and offer far better absorption of ultraviolet light, but even with delicate handling they easily develop visibility-reducing scratches. A highly abrasion-resistant coating developed by NASA provides a solution to this problem. A NASA-developed anthropometric handbook has also been used in the design and development of a new line of sunglasses.

75. A high-efficiency anti-reflection coating, developed by NASA to coat the windows of crewed spacecraft, has been applied in commercial anti-glare filters for use on personal computers to ease operators' problems with blurred vision, itching, burning eyes, eye strain, fatigue and headaches. The coating minimizes the reflected brightness to which the human eye is most sensitive and enhances image-to-background contrast, resolution and readability. Eyeglass lenses with Polarized Selective Transmission coatings block 99 per cent of the potentially harmful wavelengths while allowing the useful red, orange and green light to pass through. In addition, the lenses improve night vision and visibility through haze, fog or smog.

76. Prolonged exposure to very bright light is a significant risk factor for a variety of eye disorders, including cataracts and age-related macular degeneration. NASA researchers have developed a dye formula for use in sunglasses to reduce the transmission of ultraviolet radiation and blue light; that technology is now being used commercially for sunglasses, visors, ski goggles and prescription eyeglasses. These lenses eliminate more than 99 per cent of the harmful radiation, helping to make scenes more vivid in colour and increase the wearer's visual acuity by reducing glare.

77. Hearing impairment is a widespread problem, affecting an estimated 60 per cent of older people. Currently available hearing aids use traditional analog technology, but NASA's very large-scale integrated (VLSI) circuit technology is now being used for the development of a new digital hearing aid. Digital signal processing technology should allow a variety of improvements, including increased capability to adjust the sound amplification to the individual's hearing loss, reduced noise feedback for improved performance in noisy environments and calibration using microcomputers so that the user's hearing can be tested more quickly and accurately.

78. NASA has been working with an organization for the retarded to develop a device that can unobtrusively monitor the fullness of a person's bladder and provide feedback to the wearer or caretaker. An ultrasound technique has been found that relates the fullness of the bladder to the strength of the ultrasound echo from the back wall of the bladder. A threshold detection circuit can be adjusted to the individual wearer, providing a feedback signal when the bladder is full. Use of this device in behavioural training should increase toilet training success and enable people with bladder control problems to gain increased access to educational, social and employment opportunities.

79. For measuring the electrical activity of the body, the standard conducting electrode, which makes contact through a paste electrolyte, is generally satisfactory for short-term use in hospitals but has disadvantages that prohibit its prolonged use. The drying of the conductive paste, for example, makes it unsuitable for monitoring crews during space flight. In the mid-1970s, NASA and university researchers developed a new type of electrode consisting of a thin dielectric film over a stainless steel surface. This kind of electrode functions immediately on contact with the skin and is not affected by temperature, light, perspiration or dry, rough or oily skin conditions, thus allowing long-term use under a wide range of conditions.

E. Telemedicine

80. All space missions depend on the transmission of data on a variety of spacecraft functions and conditions to the ground for monitoring and analysis. Transmission of physiological data from sensors on the bodies of crew members has been used since the early days of human space flight to monitor heart function, respiratory patterns and other physiological parameters, particularly during critical mission phases such as launch, extra-vehicular activity and re-entry. The data from the various sensors is combined and transmitted by radio to the ground, where the signals are reconverted into physiological measurements.

81. The same technology is now being used routinely for medical applications on Earth, for example to monitor high-risk cardiac patients 24 hours a day, while still allowing such patients to leave the hospital and continue their normal daily activities. It can also provide patient-consultation capability for physicians in remote areas or at small medical facilities. Reliable physiological monitoring and communications permit a largely dispersed population to benefit from a limited supply of highly trained medical personnel.

82. One application of this technology has been Space Technology Applied to Rural Papago Health Care (STARPAHC), a project that utilizes biotelemetry to provide health care for villages of the Papago Indian Reservation in a remote area of Arizona. A mobile health unit consists of a large van containing clinical facilities and communications equipment for transmitting medical data to the Indian Hospital at Sells, Arizona. The mobile clinic visits villages on a schedule and handles over two dozen patients per day. Medical data transmitted to the hospital, including television and X-ray images, can be evaluated by physicians who can also see and talk with the patient. The physician is then able to make a diagnosis and can specify the type of treatment to be performed in the mobile health unit.

83. The 1989 Armenia-United States and Ufa-Armenia-United States medical communications links were the first examples of the use of satellite communications in support of systematic, long-term, multidisciplinary collaboration among the medical personnel of two countries. A combination of domestic and international communication satellites was used to link various United States medical centres with Yerevan, Armenia, to provide expert medical care to the victims of the earthquake in Armenia and a rail accident near the town of Ufa.

F. Medical image and data processing

84. Computer image processing techniques developed for space activities have found many applications in medicine, including imaging of brain and whole-body scans. A portable X-ray instrument, the Lixiscope (Low Intensity X-ray Imaging Scope) developed by NASA, is a self-contained, battery-powered fluoroscope producing an instant image. The X-ray source is a small amount of

iodine 123, a short-lived radioisotope, and an image needs less than 1 per cent of the radiation required by conventional X-ray systems. The Lixiscope is also being produced commercially as an industrial quality-control tool to detect minute cracks or flaws in materials, without the delays required for the development of X-ray film. The unit's portability allows for emergency use as a medical diagnostic system, for example in emergency room examinations of small children for possible bone injuries.

85. Magnetic resonance imaging (MRI) employs magnetic fields and radio waves to examine the chemical environment inside the body, including the interior of bones which are not observable by X-rays. The uses of MRI, however, have been limited by the difficulty of interpreting the data. Computer image-enhancement techniques developed to read satellite remote sensing images can now be used to produce "thematic maps" of the human body. Different colours can be used to represent different types of tissue, making such features as tumours or blood clots stand out clearly and providing valuable information to diagnostic physicians and surgeons.

86. An Automated Light Microscope System was developed by NASA to speed the analysis of human chromosomes using microscope photographs, and is now being commercially marketed. While the standard procedure takes several days to complete, the new system can automatically scan, arrange, measure and classify the images of the chromosomes in 10 to 15 minutes. The system uses digital image processing technology developed for NASA planetary missions and was designed to detect any changes in astronauts' chromosomes as a result of prolonged exposure to radiation in space. The system can also be used for diagnosing genetic abnormalities and diseases.

87. Physicians facing difficult diagnostic problems often consult medical reference books and current journals for the most recent information available. However, on spacecraft the storage space is extremely limited, and essential information and data will need to be stored in computerized rather than printed form. For the International Space Station, NASA is therefore developing a medical operations electronic database. A microcomputer-based medical decision support system is also being developed to provide medical personnel with a small library of essential medical knowledge, including graphs, pictures and illustrations. The final system will use artificial intelligence techniques to recognize key words and patterns while searching through tens of thousands of medical documents. Aside from its use in space, such a computerized medical library could ultimately be put on laser disks and made available to physicians in any office with a personal computer or terminal.

G. New drugs and medical materials

88. A knowledge of the molecular structure of medical drugs is important in understanding how they work as well as in developing new drugs. The growth of crystals under conditions of microgravity, together with ground research, can provide important information for the interpretation of molecular structure. Ground-based research on growing protein crystals in preparation for space

experiments has resulted in the growth of crystals of human serum albumin, enabling researchers to determine the three-dimensional molecular structure of this protein to a resolution of 0.6 mm. Because serum albumen is important to the transport of many physiological and pharmaceutical molecules in the bloodstream, the knowledge of its structure will help in the design of new drugs. Experiments on the growth of influenza virus crystals were conducted on the Mir space station in cooperation with Australian scientists for the purpose of determining the structure of the virus and designing drugs to counter its effects. The results of the experiments are still being evaluated.

89. Microgravity conditions can also provide opportunities for studying the growth of cell cultures. As a result of space research, new ground-based systems for growing cell cultures have been developed, simulating some aspects of microgravity in order to obtain three-dimensional tissues rather than a flat sheet of cells that typically results from traditional culture techniques. Research has been carried out on board the Mir space station in cooperation with scientists from the United States and Sweden on the growth of cell cultures in conditions of microgravity for the production of pharmaceutical products.

90. A new anti-bacterial agent, Lactobacterin, was developed in the USSR for prophylaxis against changes in the intestinal flora of cosmonauts on long-duration space flights. It is resistant to digestive fluids and enzymes, has exceptionally high adhesiveness and is highly antagonistic to disease-producing microorganisms. This agent can be used for the treatment of both children and adults suffering from colitis of varying etiologies, for bacterial dysfunctions resulting from the use of antibiotics, and for ensuring antiseptic conditions in obstetrical and gynecological practice. The agent appears to have no harmful side-effects or limitations on its use.

91. The wide use of such aerospace composite materials as carbon-carbon, carbon plastics, glass-fibre plastics and others is due to their high mechanical strength, low specific weight, heat resistance, elasticity, resistance to corrosion and chemical stability. Carbon-carbon composites in particular have many applications in health care, including for artificial tendons, ligaments, eardrums, blood vessels and other artificial implants. They are less likely than alternative materials to induce clotting, and their use in medicine can substantially reduce recovery times, avoid the use of repeat operations and shorten rehabilitation periods.

92. Since space flight crews may need emergency medical care upon return to Earth, the USSR developed the Ecosan portable medical station for preliminary examination of cosmonauts at the landing site. The facility is adaptable for use in emergencies to provide on-site emergency medical care to victims of accidents or natural disasters. The station comprises several inflatable modules, equipped with the most advanced medical instruments, including those developed for use in space. Field tests in the region of the far north (Cape Schmidt, Chukotka) and in the Kara Kum desert have demonstrated the applicability of this system in various geographic regions and under extreme conditions. Similarly, a portable dental kit weighing less than 4 kg and

comprising a miniature drill, a set of dental instruments, forceps for tooth extraction, dental-filling material and pain-killing drugs can be utilized for administering dental first aid in the field during expeditions and for preventive-care examinations of people in isolated areas.

IV. PROMOTING THE APPLICATIONS OF SPACE LIFE-SCIENCE RESEARCH

93. As indicated in the preceding sections of the present report, extensive research has been conducted in space on a variety of topics related to medicine. While some of this space research has been applied to conventional medicine, most of the results of space research in the life sciences, as in other fields, remain within the domain of space research. In space medicine as in other branches of space science and technology, there are substantial practical obstacles to the transfer of knowledge from space research to terrestrial applications. The process and the problems of spin-off of benefits from space research to non-space applications has been examined in the report on spin-off benefits of space technology (A/AC.105/486).

94. As noted in that earlier study, some transfer of technology from space research to non-space applications takes place through existing processes such as scientific conferences and publications, formal and informal technical cooperation between space and non-space institutions and the mobility of scientists and engineers between institutions or within institutions that have space and non-space activities. Many space programmes conduct space activities through contracts with industries whose primary business is in other areas, facilitating the transfer of space technology to those other areas. Space scientific research is also often conducted by space agencies in cooperation with researchers from universities or research institutes, which can use the resulting knowledge and technology in other areas.

95. None the less, there are still major obstacles to the transfer of technology between different economic sectors, between different professions and between different institutions. Much of the transfer that does occur takes place locally and often through chance contacts. There would therefore seem to be a large unused potential for further transfer of space science and technology to economic and social applications in other areas. To help overcome these obstacles and develop that potential, some countries have established or are establishing programmes specifically devoted to technology transfer.

96. NASA has the most highly developed programme for transferring science and technology developed in the space programme to other sectors of the economy. The programme is managed by the Technology Utilization Division within the NASA Office of Commercial Programs. Each of NASA's nine field centres has a Technology Utilization Officer, and a large number of industrial applications centres have been established throughout the country, mostly within universities or other research institutes. This programme is supported by the Scientific and Technological Information Facility, which publishes a variety of publications to disseminate the results of NASA research. The transfer of

the results of space medical and biotechnology research are an important part of that programme.

97. The major programme of the European Space Agency for promoting the widest possible use of the science and technology developed by the agency is the Information Retrieval Service (ESA-IRS), including the life-science information system BIOSIS. That programme is now being expanded in a five-year effort in order to improve the dissemination of information to the scientific and educational community. ESA is working with NASA to coordinate their information systems, including collaborative database development, document translation, development of computer access to databases and interconnectivity between NASA and ESA electronic retrieval services. This should contribute to the world-wide availability and exploitation of the information contained in both systems.

98. Other countries have also been active in the field. In the USSR, the Institute for Medico-Biological Problems of the USSR Ministry of Health was the main institution responsible for conducting and coordinating space life-science research and for promoting the applications of space research to conventional medicine and health care. India and China have also conducted space life-science research and applied the results to non-space activities.

99. To further promote the transfer of the results of space medical and biological research to practical medical applications on the international level, particularly for developing countries, efforts could be made to facilitate international access to the existing information systems and publications on space medicine and biology and their practical applications. Such efforts might include facilitating remote computer access to the information systems, providing such access free or at reduced charges for scientists in developing countries, publishing and disseminating information on how to use the systems and providing training in the effective use of the systems.

100. The first step in such an effort might be to conduct a survey of existing information systems covering space life-science research and applications, including the arrangements for international access to those information systems. The survey might focus particularly on arrangements for remote computer access to such information systems and on the availability of international electronic data exchange networks in developing countries. This survey would provide a basis for planning further activities to promote the international exchange of information on the practical applications of space life-science research.

101. The Committee on the Peaceful Uses of Outer Space could play a useful role in promoting the exchange of information and experience on the practical applications of the results of space medicine. This could be done through presentations during the meetings of the Committee and the Scientific and Technical Subcommittee, through the submission of reports by Member States for circulation as Committee documents and by sponsoring analytical studies on the question.

Notes

1/ Official Records of the General Assembly, Forty-fourth Session, Supplement No. 20 (A/44/20), para. 28.

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